ANTALYA 2050:
CLIMATE RESILIENCE AND GREEN TRANSITION REPORT

Climate Risks, Urban Adaptation, Water Security and Sectoral Carbon Management in the Context of COP31

A Strategy and Policy Action Plan for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

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PROJECT SUMMARY

This report has been prepared to assess Antalya's current and future vulnerabilities to climate change through a multisectoral approach and to develop actionable policy, planning and investment recommendations to enhance the city's climate resilience. Antalya's coastal setting, together with the geographical concentration of intensive tourism activity, substantial agricultural production, rapid urbanisation, forests, water resources and biodiversity, gives rise to multiple, mutually reinforcing climate risks across the city.

The study identifies extreme precipitation and flooding, heatwaves, drought, forest fires, sea-level rise, coastal erosion, deteriorating water quality and extreme weather events as the principal climate hazards. It assesses their impacts on urbanisation and spatial planning, the building stock and infrastructure, energy, water management, agriculture, industry, tourism, coastal areas, ecosystems and public health. The underlying approach is to treat climate risks as a fundamental input into planning and investment decisions, as well as a concern for post-disaster response.

In the energy sector, key areas include energy efficiency, renewable energy, energy storage, green hydrogen, the circular economy, low-carbon transition in industry and organised industrial zones, carbon markets and green finance. Water management priorities include water supply security, water loss reduction, sponge city applications, wastewater reclamation, modern irrigation, water efficiency in tourism and industry, and data-driven decision support systems. In agriculture and tourism, sustainable greenhouse production, biodiversity conservation, resource efficiency, green tourism and investment in resilient infrastructure are identified as key areas for transformation.

The report's overarching conclusion is that Antalya needs an integrated climate resilience framework founded on measurable targets, shared data infrastructure, institutional coordination and sustainable financing, in place of isolated and fragmented projects. Linking urban development decisions to climate risk maps, retrofitting existing buildings and infrastructure, effectively managing water and energy demand, scaling up nature-based solutions and supporting low-carbon production models are intended to strengthen Antalya's disaster resilience and economic sustainability.

Priority Action Areas

- Integrating climate risks into zoning, transport, infrastructure and investment decisions.
- Advancing water security, energy efficiency and the transition to renewable energy through joint programmes.
- Scaling up low-carbon, resource-efficient and circular models in agriculture, tourism and industry.
- Applying a risk-based approach to protecting coastal areas, forests, agricultural land and areas of high biodiversity sensitivity.
- Strengthening climate finance and shared data, monitoring and decision support systems.

CHAPTER

01

ANTALYA
2050

ANTALYA 2050 / COP31

CLIMATE CHANGE RISKS AND THEIR SECTORAL IMPACTS IN ANTALYA

CLIMATE RESILIENCE · URBANISATION · DISASTER MANAGEMENT

- Climate hazards
- Urban adaptation
- Ecosystems and society

A Strategy for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

Climate Change Risks and Their Sectoral Impacts in Antalya

1. Climate Hazards in Antalya

Antalya lies within the Southern European–Eastern Mediterranean climate zone, among the areas of the Mediterranean Basin most vulnerable to climate change. IPCC assessments identify the Mediterranean as a "climate change hotspot", indicating that rising temperatures, disruptions to precipitation patterns, extreme weather events, drought, forest fires and sea-level rise are progressing more rapidly in this region than the global average. Antalya is one of the provinces in Türkiye where this vulnerability is most acutely experienced. The geographical concentration of tourism, agriculture, coastal settlements, forests, biodiversity and water resources exposes the city to multiple climate risks.

A combined assessment of Antalya Metropolitan Municipality's Sustainable Energy and Climate Action Plan (SECAP) studies, the Antalya Provincial Disaster Risk Reduction Plan (İRAP), observations by the Turkish State Meteorological Service (MGM), academic studies and recent disaster records indicates that climate hazards in the city are already a measurable reality. In particular, the floods, tornadoes, extreme precipitation, forest fires, heatwaves and droughts experienced during the 2018–2026 period point to a substantial shift in Antalya's climate regime.

1.1. Extreme Precipitation and Flooding

A marked increase in the frequency of short-duration, high-intensity precipitation events has been observed in Antalya. Particularly during autumn and winter, rainfall totals approaching monthly levels can occur within a few hours, increasing the risk of flooding in the urban centre and of floods and runoff-induced erosion in rural areas. Antalya's topography, rapid urbanisation, expanding impervious surfaces, alterations to stream channels and inadequate stormwater infrastructure further exacerbate flood risk.

Extreme precipitation in central Antalya and the districts of Serik, Aksu, Kemer and Manavgat in 2018, 2019, 2021, 2024, 2025 and 2026 caused the inundation of underpasses, damage to agricultural land, the destruction of greenhouses, coastal flooding and substantial economic losses. Floods occurring during the tourism season place particularly significant economic pressures on transport infrastructure, hotels, marinas and coastal facilities.

Another major consequence of extreme precipitation is the transport of pollutants into receiving waters through surface runoff. Pesticide and fertiliser residues washed off agricultural land, together with heavy metals, microplastics and hydrocarbons carried from urban areas, degrade coastal water quality. This creates significant risks for ecosystems, public health and the tourism economy.

Recent measures undertaken by ASAT, including the renewal of stormwater drainage networks, the separation of combined sewer systems, the rehabilitation of drainage lines with insufficient capacity to convey flood flows, and the renewal of drinking water infrastructure, represent important adaptation measures aimed at reducing existing risks. However, given the increasing frequency of extreme precipitation, there is a risk that existing infrastructure will become inadequate in the future.

1.2. Extreme Weather Events

Antalya has become one of the provinces in Türkiye most frequently affected by tornadoes and severe storms. Rising sea surface temperatures in the Mediterranean, increasing atmospheric moisture and intensifying convective systems create conditions conducive to tornado formation.

The tornado disaster that occurred near Antalya Airport in 2019 caused millions of dollars in damage to greenhouses, vehicles, aircraft and energy infrastructure, as well as numerous injuries and fatalities.

Similarly, increasingly frequent hailstorms, severe storms and tornadoes in Kumluca, Finike, Serik and Aksu cause substantial economic losses, particularly in protected cultivation.

Agricultural insurance data indicate that hailstorms, tornadoes and extreme precipitation now account for a substantial share of climate-related disaster damage in Antalya. Structural damage in the greenhouse production sector also places pressure on food supply security, in addition to causing economic losses.

Storm surges in coastal areas pose a growing risk to marina infrastructure, waterfront developments and tourism facilities. These events also contribute to the acceleration of coastal erosion.

1.3. Cold Spells

Despite Antalya's location within the Mediterranean climate zone, sudden temperature drops and extreme frost events continue to occur. Abrupt cold spells, particularly in inland areas and higher-elevation districts, have substantial impacts on agricultural production.

Climate change involves changes beyond rising temperatures; disruptions to atmospheric circulation can also increase the likelihood of both extreme heat and extreme cold events. The expansion of citrus, avocado and tropical fruit production in Antalya has made agricultural systems more vulnerable to sudden frost events.

Sudden temperature drops following early flowering are particularly likely to increase crop losses. This places pressure on both farmers' incomes and the regional food economy.

1.4. Sea-Level Rise

Sea-level rise is a long-term but highly significant threat to Antalya. Studies conducted in the Gulf of Antalya indicate that rising sea levels will lead to shoreline retreat, coastal flooding, saltwater intrusion and land loss.

Studies using satellite data and digital elevation models indicate that more than 250 km^2 of land could be lost along the Gulf of Antalya over the next 60–80 years. This risk is particularly significant for low-lying coastal areas, deltas, wetlands, tourism facilities and coastal agricultural land.

One of the most critical consequences of sea-level rise is increased saltwater intrusion into coastal aquifers. In Antalya, aquifers already under pressure from intensive groundwater abstraction, particularly in the Aksu, Serik and Manavgat plains, are becoming more vulnerable to seawater intrusion. Salinisation has long-term implications for drinking water sources, irrigation water quality and agricultural productivity.

Furthermore, the loss of coastal wetlands entails a reduction in important carbon sinks. Wetlands, reed beds and coastal ecosystems are critical both for biodiversity and for their carbon storage capacity. Their loss as sea levels rise will reduce Antalya's natural carbon sequestration capacity.

1.5. Heatwaves and Drought

Heatwaves are among the most rapidly intensifying climate hazards in Antalya. Recent years have seen substantial increases in the number of tropical nights, the duration of high-temperature conditions and apparent temperatures. The urban heat island effect, driven by urbanisation and the expansion of concrete surfaces, prevents night-time temperatures from falling, particularly in densely built-up areas such as Muratpaşa, Kepez and Konyaaltı.

These conditions pose significant public health risks. Older people, children, outdoor workers and individuals with chronic conditions are becoming more vulnerable to heat stress. Increased air-conditioning use, meanwhile, raises energy demand and associated indirect carbon emissions.

Drought places critical pressure on Antalya's water security. Irregular precipitation patterns, declining snow cover, increased evaporation and intensified groundwater abstraction place particular pressure on agriculture and tourism.

During the tourism season, the population increases severalfold, dramatically raising demand for drinking water and other domestic water uses. Golf courses, hotels and intensive landscape irrigation increase water consumption, while drought periods intensify competition between agricultural and urban water uses.

Drought also weakens forest ecosystems, facilitates the spread of pests and increases fire risk.

1.6. Forest Fires

Antalya is one of the provinces in Türkiye most severely affected by forest fires. The 2021 Manavgat fires, in particular, have been regarded as one of the largest climate-related disasters in both Türkiye and the Mediterranean Basin.

The fires destroyed extensive forest areas, affected numerous settlements and damaged agricultural land, greenhouses, livestock operations and tourism facilities. Forest loss extends beyond the loss of trees: it also entails reduced carbon sinks, habitat fragmentation, biodiversity loss, soil erosion and disruption of the hydrological cycle.

In burned areas, soil organic matter declines, while surface runoff and flood risk increase following rainfall. This also creates a risk of post-fire flooding.

Although Antalya's Turkish red pine forests are adapted to the Mediterranean fire regime, rising temperatures, low humidity and prolonged drought are making fire behaviour more destructive. The combination of high temperatures and strong winds particularly increases the risk of megafires.

1.7. Water Pollution

Climate change has multidimensional effects on water quality in Antalya. Reduced flows and rising temperatures lower dissolved oxygen levels in aquatic environments and increase the risk of eutrophication.

During periods of extreme precipitation, sewer overflows, surface runoff and untreated discharges increase the risk of microbiological contamination, particularly in coastal waters. This also threatens Blue Flag beaches, which are important tourism assets.

Lower flows during drought periods reduce the capacity of receiving waters to dilute pollutants, making pollution impacts more pronounced. Declining groundwater levels may also increase nitrate, salinity and heavy metal concentrations.

Furthermore, rising seawater temperatures accelerate the spread of invasive species and alter the ecological balance of coastal ecosystems.

1.8. Communicable Diseases

Climate change is also creating new public health risks in Antalya. Rising temperatures and changing humidity conditions are expanding the habitats of mosquitoes and other disease vectors.

The risk of the spread of vector-borne diseases, such as West Nile virus infection and dengue, is increasing across the Mediterranean Basin. Longer warm periods extend vector breeding seasons and disease transmission periods.

Standing water following extreme precipitation and flooding can increase vector populations, while sewer overflows and risks to drinking water systems raise the likelihood of waterborne diseases.

Deteriorating air quality and ozone formation, particularly during heatwaves, can also increase the incidence of respiratory illness. In a city such as Antalya, with a substantial older population and a dramatic seasonal population increase during summer, these conditions place additional pressure on healthcare systems.

2. Climate Change Projections for Antalya

The Mediterranean Basin is among the regions expected to be most severely affected by climate change globally and is described in the international literature as a "climate change hotspot". Reports published by the Intergovernmental Panel on Climate Change (IPCC), Mediterranean Experts on Climate and Environmental Change (MedECC), the United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) and the European Environment Agency indicate that warming in the Mediterranean will exceed the global average, precipitation patterns will change substantially, and the region will become one of the world's most vulnerable areas in terms of water stress, drought, extreme weather events, forest fires and coastal pressures. Given its coastal systems, intensive tourism activity, agricultural production capacity, forests and rapidly increasing population pressures, Antalya is considered one of the cities in Türkiye likely to be most severely affected by these changes.

Scientific projections indicate that warming in the Mediterranean Basin will be approximately 20% greater than the global average. While the current global temperature increase relative to pre-industrial levels is approximately 1.1–1.3°C, warming in the Mediterranean Basin has already approached 1.5°C. Under scenarios of continued high greenhouse gas emissions, average temperatures in the Mediterranean are projected to increase by 4–6°C by the end of the century. This warming will affect the duration, frequency and intensity of heatwaves, as well as summer temperatures. In humid coastal cities such as Antalya, apparent temperatures may reach levels that threaten human health.

Antalya is expected to experience a substantial increase in tropical nights, defined as nights when temperatures do not fall below 20°C. This will pose significant health risks, particularly for older people, children, individuals with chronic conditions and outdoor workers. The urban heat island effect associated with dense development in urban centres will further intensify heat stress by limiting night-time cooling. These changes will also directly affect energy consumption. Electricity demand is expected to rise substantially, particularly during summer, owing to increased air-conditioning use. This may place pressure on energy infrastructure, increase energy costs and raise indirect carbon emissions.

Drought and pressure on water resources are among the areas of strongest scientific consensus concerning the Mediterranean. According to MedECC reports, precipitation in the region is expected to decline by 10–30%. Its distribution throughout the year will also change, with prolonged dry periods increasingly followed by brief but exceptionally intense rainfall events. For Antalya, the principal risk extends beyond declining precipitation. Increased evaporation associated with rising temperatures, reduced snow cover, declining groundwater recharge and growing water demand will place substantial pressure on the city's water security.

In Antalya, where tourism is a major sector, the severalfold increase in population during summer makes the effects of climate change on water resources particularly critical. Considering golf tourism, landscape irrigation, high hotel water consumption and agricultural irrigation together, the balance between water supply and demand is expected to become increasingly fragile. If groundwater levels continue to decline, seawater intrusion into coastal aquifers may intensify, exacerbating salinisation in the Aksu, Serik and Manavgat plains. Saltwater intrusion will threaten drinking water quality as well as agricultural productivity.

Forest fires will be another major consequence of climate change for Antalya. IPCC assessments and Mediterranean climate projections indicate that longer heatwaves, low humidity and prolonged drought will substantially increase fire risk in the region. Larger and more difficult-to-control fires are expected in Antalya, particularly in areas dominated by Turkish red pine forests. Scientists regard the major Manavgat fires of 2021 as an early indication of the future fire regime. Longer fire seasons, simultaneous large fires and sustained high-intensity fire activity even at night are considered plausible future developments.

These impacts extend beyond forest loss. Forests are important carbon sinks: large fires release stored carbon into the atmosphere and destroy ecosystems capable of sequestering carbon in the future. Habitat fragmentation, biodiversity loss, soil erosion and disruption of the hydrological cycle are further indirect consequences. Areas stripped of vegetation by fire are also expected to face increased flood risk during sudden rainfall events.

Sea-level rise is another major projected change in the Mediterranean Basin. IPCC scenarios indicate that sea levels could rise by approximately 0.5–1 metre by the end of the century. For Antalya, this implies coastal erosion, coastal flooding, wetland loss and damage to coastal infrastructure. Coastal systems in Lara, Belek, Konyaaltı and delta areas are expected to become particularly vulnerable. The combined effects of rising sea levels and more consequential storm surges will increase economic risks to tourism facilities and coastal investments.

Changes to coastal systems will extend beyond physical land loss. Coastal wetlands, reed beds and seagrass meadows are important carbon sinks. Damage to these ecosystems will reduce Antalya's natural carbon storage capacity. Sea-level rise and saltwater intrusion may also reduce productivity on coastal agricultural land.

Marine ecosystems are already experiencing rapidly rising seawater temperatures in the Mediterranean. Marine heatwaves have become more frequent in recent years, and the trend towards tropicalisation is intensifying. These processes may substantially alter marine biodiversity in the Gulf of Antalya. The spread of invasive species of tropical origin, declines in some native species, shifts in fish population distributions and declining oxygen levels in marine ecosystems are among the principal anticipated impacts. Rising seawater temperatures also increase the atmospheric energy available to support tornadoes and severe convective systems.

Extreme weather events will be among Antalya's most prominent future climate risks. Scientific studies indicate that the atmosphere's increased moisture-holding capacity will lead to more frequent short-duration, high-intensity precipitation events in the Mediterranean. This may increase the occurrence of flash floods, flooding, hailstorms, tornadoes and severe storms in Antalya. In densely urbanised areas, expanding impervious surfaces will prevent rainwater infiltration and exacerbate flooding. Recent tornadoes and extreme precipitation events in Antalya suggest that such disasters may become more frequent and destructive.

The economic implications of climate change are also substantial for Antalya. In a city whose economy depends heavily on tourism, agriculture and coastal activities, climate-related disasters are expected to increase insurance costs, infrastructure damage and economic vulnerability. Reduced thermal comfort during the summer tourism season, restrictions on outdoor activities during certain periods and mounting pressure on water resources may directly affect tourism. In agriculture, drought, heat-related yield losses, the spread of pests and rising irrigation costs will be major challenges.

Overall, international climate projections clearly indicate that the Mediterranean Basin and Antalya will face multidimensional climate pressures over the coming decades. Hotter summers, longer droughts, larger forest fires, more frequent extreme weather events, sea-level rise, pressure on water resources and

biodiversity loss are emerging as the principal climate hazards shaping Antalya's future. Current disasters are increasingly regarded as early signals of the future climate regime rather than exceptional events.

3. Impacts of Climate Hazards on Urbanisation in Antalya

Discussions of urbanisation and climate resilience largely focus on zoning plans and urban infrastructure. However, a critical layer determining the climate performance of spatial decisions lies at the building scale and within the building envelope. Urban temperature maps, flood damage statistics and post-earthquake damage assessments show that, alongside strategic planning decisions, the form, surface materials, envelope detailing and ground-floor configuration of individual buildings directly influence climate vulnerability.

This section assesses the impacts of climate change on urbanisation, spatial planning, transport, energy and infrastructure systems, coastal areas and the urban water cycle. Its purpose is to establish how climate risks should be translated, through design principles, into planning decisions, plan provisions, implementation instruments and urban development strategies, rather than to produce engineering designs or detailed feasibility studies.

Strengthening urban climate resilience requires each building to be designed for local climatic conditions, constructed using materials that support energy and water efficiency, and integrated with surrounding open spaces, green infrastructure and public spaces, alongside strategic planning and zoning decisions. Architectural design decisions are therefore treated as essential instruments that complement planning decisions in climate adaptation and disaster risk reduction [1, 2].

From an urban planning perspective, the central challenge is to integrate climate risks with land-use decisions, site selection, development densities, transport systems, open and green space networks, coastal uses, infrastructure capacity, natural resource conservation, urban regeneration and spatial development strategies, rather than addressing them solely within disaster, infrastructure or environmental management.

Because climate change directly affects every component of urban space, planning processes require collaboration across disciplines, particularly urban planning, environmental engineering, civil engineering and geomatics engineering. Environmental engineering contributes critically to water resource protection, wastewater and stormwater management, air quality and the sustainability of ecosystem services. Civil engineering plays an important role in designing resilient infrastructure systems, transport networks and buildings adapted to climate risks.

Geomatics engineering enables the spatial analysis of risks and provides decision-makers with scientific evidence through geographic information systems, remote sensing, digital elevation models and disaster risk maps.

Within this framework, climate adaptation and disaster risk reduction should be placed at the centre of spatial planning. Flooding, drought, heatwaves, forest fires, sea-level rise and coastal erosion should be considered at every level of the planning hierarchy, from strategic spatial plans to detailed implementation zoning plans. In rapidly growing cities such as Antalya, which face intensive tourism pressure and direct climate impacts, key priorities should include safeguarding ecological limits, developing blue–green infrastructure, expanding water-sensitive urban design, promoting energy-efficient and low-carbon settlements, reducing transport emissions and establishing disaster-resilient urban infrastructure.

The approaches proposed below therefore seek to establish a comprehensive framework for climate-resilient urbanisation in Antalya, integrating physical planning decisions with environmental sustainability, engineering solutions, spatial data management and disaster risk reduction.

3.1. Urbanisation, Spatial Planning and Climate Resilience

3.1.1. Scope and Current Situation

Antalya's coastal setting, concentration of tourism and service activities, rapid population growth, agricultural land and wildland–urban interfaces create an urban development pattern exposed to climate change. Extreme precipitation and flooding, heatwaves, drought, forest fires, sea-level rise and coastal flooding should be treated as planning inputs that directly influence spatial development decisions, alongside their environmental implications.

In spatial planning, climate resilience encompasses both a city's capacity to recover after a disaster and its capacity to establish land-use patterns that avoid creating risks beforehand. Zoning plans, explanatory planning reports and plan provisions should therefore incorporate information on flood hazards, the urban heat island effect, water scarcity, coastal risks, fire risk, infrastructure capacity and transport continuity. In accordance with the planning hierarchy, strategic decisions at higher levels must guide detailed implementation plans. This is essential to prevent fragmented plan amendments from obscuring climate risks.

Climate-resilient planning in Antalya should focus on managing development pressure while devising regeneration and improvement strategies that reduce risks in existing built-up areas. Climate risks should therefore be incorporated into the planning hierarchy, urban density decisions, the selection of development areas, open and green space systems, urban design principles, and monitoring and evaluation mechanisms.

Climate resilience should also encompass architectural design parameters such as urban block configuration, building heights, street geometry and the sky view factor (SVF), which directly influence natural ventilation and urban heat island formation. Similarly, flood-resilient architectural principles concerning ground-floor elevations, basement uses, building materials and the positioning of building services should be considered in flood-prone areas. Passive adaptation measures, including cool roofs and highly reflective façades in existing buildings, should be recognised as complementary tools for enhancing urban resilience. This enables climate adaptation to be addressed comprehensively at planning, building and urban design scales.

3.1.2. Identification of Problems

- **Failure to incorporate climate risks into binding planning decisions:** Information on flooding, urban heat islands, coastal flooding, drought and fire risk often receives limited coverage in explanatory planning reports and does not sufficiently influence land-use decisions, density controls or plan provisions.
- **Fragmented plan amendments and density increases:** Changes to density, land use and development conditions at block or parcel scale increase urban vulnerability when assessed without considering infrastructure capacity, open space requirements, transport demand and climate risks.
- **Failure to select development areas on the basis of risk and carrying capacity:** The designation of new settlement areas requires the joint assessment of water resources, drainage capacity, flood-prone areas, wildland–urban interfaces, agricultural land, transport accessibility and evacuation capacity.

- **Insufficient consideration of heat island and microclimatic effects in planning:** Urban environments characterised by extensive hard surfaces, insufficient shade, fragmented green spaces and obstructed ventilation corridors intensify heatwave impacts.
- **Institutional disconnect between planning and disaster management data:** Standardised procedures are lacking for translating data produced by the Disaster and Emergency Management Authority (AFAD), municipalities, infrastructure agencies, and environmental and climate units into planning decisions through a shared GIS platform.
- **Failure to assess social vulnerability alongside climate risks:** Older people, children, low-income groups, neighbourhoods with limited transport access and densely built-up areas experience different levels of climate risk. Planning decisions should explicitly recognise these differences.
- In building permitting and zoning implementation, building orientation, façade height ratios and spacing between buildings are assessed primarily in terms of sunlight access and daylight separation distances, without accounting for the thermal effects of urban canyon geometry.
- Buildings in new residential and mixed-use blocks are not positioned perpendicular to prevailing winds, and opportunities for natural ventilation are not assessed during design.
- Permeable ground and green surface ratios at block scale are not checked during architectural project approval, allowing extensive hard surfacing to contribute to flooding and urban heat island effects.
- Bioclimatic design and urban climate literacy remain largely elective subjects in architectural education and professional practice, while climate performance calculations are not systematically integrated into architectural design.
- Türkiye lacks a binding standard or regulation defining building-scale flood-resilient architectural design criteria. Ground-floor elevations are determined according to general zoning-plan reference grades rather than flood risk assessments.
- Basement construction in flood-prone areas is not restricted through permitting procedures. Critical mechanical and electrical infrastructure, including transformers, pump rooms and electrical distribution panels, continues to be located in basements. This substantially increases post-flood repair costs and delays the restoration of building functionality [4].
- Architectural approval procedures in coastal areas lack requirements for building setbacks and minimum ground-floor elevations calculated using storm surge and sea-level rise scenarios.
- A pre-design climate assessment incorporating climate scenarios is not yet a requirement in Türkiye's permitting procedures and remains at the individual discretion of the project designer.
- Türkiye's zoning regulations do not specify minimum solar reflectance values for roofing and façade materials. The thermal performance of roof coverings is not checked during building permitting.
- Dark bituminous membranes and roof tiles predominate in the existing building stock. Their daytime surface temperatures can reach 70–80°C, increasing both building cooling loads and urban heat accumulation.
- Zoning regulations and permitting procedures lack incentives for green roofs. Gaps in architects' and contractors' knowledge concerning additional structural loads and coordination of waterproofing layers hinder wider adoption.

- Users and project designers lack sufficient technical knowledge of the biological risks, including mould and pests, and maintenance requirements associated with living walls under Antalya's humid summer conditions.
- Shading in public spaces is given secondary priority because of aesthetic considerations, security concerns and maintenance costs. Thermal comfort under intense sunlight is not adequately provided in playgrounds, at public transport stops or along pedestrian routes.

3.1.3. Proposed Solutions

Urban Density and Planning

- **A density model based on risk and carrying capacity:** Population density, floor area ratio, building height and land-use decisions should be determined by water supply and sewerage capacity, stormwater drainage, transport capacity, open and green space provision, access to emergency assembly areas and microclimatic conditions, alongside ownership and investment demands. These criteria should be directly incorporated into architectural permitting, with all calculations based on the proposed number of self-contained units and net construction floor area.
- **Balanced urban development and management of development pressure:** Urban growth should be guided by ecological limits and disaster risks. Planning decisions should protect stream channels, areas with high flood risk, sensitive coastal zones, wildland–urban interfaces and land whose agricultural character must be preserved. A phased permitting and settlement model should be introduced across Antalya.
- **Climate suitability assessments for new settlement areas:** Multicriteria suitability assessments should evaluate slope, geology, hydrology, flood and fire risks, transport accessibility, infrastructure service provision and water resources. Areas found unsuitable should be excluded from development plans or restricted to low-density, controlled and climate-adapted uses.
- **Planning that reduces urban sprawl while preventing excessive concentration:** Climate-resilient urbanisation should curb uncontrolled sprawl while avoiding densities that eliminate green spaces, ventilation corridors and community facilities. The compact city approach should therefore be implemented alongside ecological and social infrastructure standards. All planning measures that increase density should be subject to the relevant forms of impact assessment, with the findings mandatorily submitted to investors and the competent authorities.
- **A building-scale sky view factor (SVF) standard:** An architectural design guide should be prepared to govern block layouts in new development areas along Antalya's prevailing southwest–northeast wind axis. It should include an upper limit for the building-height-to-street-width ratio, with a maximum façade height/street width ratio of ≤ 1:1 as the proposed hot-climate threshold; a minimum orientation angle responsive to regional prevailing winds; and mandatory open-air ventilation corridors within blocks [2, 3].
- **Building form and climate compatibility certification:** For new buildings above a specified size, for example 2,000 m² or more, permitting should require an "Architectural Climate Compatibility Declaration" confirming compliance with bioclimatic design criteria. The declaration should address building orientation, solar control, façade height geometry, natural ventilation strategies and ground permeability. It should be signed by project architects accredited by the Chamber of Architects. This would establish building-scale climate performance requirements alongside planning controls [1, 2].

- **Mandatory professional development in bioclimatic design:** Relevant institutions should develop a certification programme entitled "Bioclimatic Architecture in Hot and Humid Climates" covering all provinces within Türkiye's Mediterranean climate zone and incorporate it into professional competency requirements. The programme should include practical workshops on SVF analysis, solar shading design, natural ventilation simulation and the integration of vegetated surfaces. This measure is critical to ensuring that future buildings are appropriately designed from the outset [1].

Climate-Risk-Sensitive Zoning Plans

- **Climate risk maps as planning annexes:** Maps of flooding, flash flooding, heat stress, fire, coastal flooding, drought and infrastructure vulnerability should form analytical map sheets that guide planning decisions, rather than serving solely as background information in explanatory reports.
- **Climate adaptation provisions in plan notes:** Detailed implementation zoning plans should include explicit provisions on permeable surface ratios, shading, stormwater management, opportunities for green roofs and walls, tree planting, open space continuity, parking surfaces, renewable energy infrastructure and emergency access.
- **Climate impact assessments for plan amendments:** Climate risk and disaster impact assessments should be mandatory for amendments that increase density, change land use or affect sensitive areas such as coasts, stream channels, agricultural land and wildland–urban interfaces.
- **Consistent integration of risk across the planning hierarchy:** Climate risks identified in higher-level plans should inform land-use and density decisions in 1:5,000-scale master zoning plans and development conditions, building setbacks, open space allocations and plan provisions in 1:1,000-scale implementation zoning plans.
- **A GIS-based monitoring system:** Planning decisions and disaster and climate risks should be monitored within a shared database. Plan amendments should be recorded, and changes in the city's overall risk burden should be reported periodically.
- **Guidelines for flood-resilient architectural design:** A "Guide to Architectural Design in Flood-Prone Areas" should be prepared, drawing on ASCE 24-24 while reflecting Türkiye's flood regimes, building stock and local zoning system. It should specify minimum ground-floor elevations according to flood risk, restrictions on basement use to parking and building services spaces constructed with flood-resistant materials, minimum installation elevations for critical mechanical and electrical systems, and standard details for flood doors and barriers.
- **An architectural climate adaptation protocol for coastal buildings:** Applications for new building permits along Antalya's coast should include a "Coastal Risk Architectural Assessment" incorporating sea-level rise and storm surge scenarios over a minimum 50-year horizon. Relevant institutions should define the assessment standards. This approach would also clarify interdisciplinary responsibilities by assigning coastal protection zones to urban planning and building elevations to architectural design [4, 6].
- **Drought-adapted building design and water efficiency standards:** In response to increasing drought pressure, the Ministry of Environment, Urbanisation and Climate Change should be approached to establish rainwater harvesting and reuse systems as mandatory components of architectural projects for new buildings. Standardised design calculation notes should address roof area, storage volume and intended use. A policy proposal should also be prepared to extend the

scope of Türkiye's existing Regulation on Energy Performance in Buildings (BEP-TR) to include water efficiency [1, 6].

Urban Design to Mitigate the Heat Island Effect

- **Identifying priority neighbourhoods for heat risk:** Neighbourhoods should be prioritised through a combined assessment of surface temperature, building density, access to green space, continuity of shade, the proportion of older residents and social vulnerability indicators.
- **Continuity of green–blue infrastructure:** Parks, urban forests, stream corridors, coastal areas, central reservations, pedestrian routes and public open spaces should be planned as an integrated system supporting urban cooling and air circulation.
- **Shaded public space design:** Standards for natural and built shading should be developed for pedestrian routes, public transport stops, squares, school surroundings, healthcare facilities and emergency assembly areas.
- **Surface materials and permeability:** Parking areas, squares, pedestrian routes and extensive paved surfaces should use materials with high reflectance, low heat storage capacity and, where feasible, permeability. Plan provisions and urban design guides should support these requirements.
- **Protection of ventilation corridors:** Development decisions that obstruct airflow should be avoided, particularly in densely built-up areas. Valleys, open spaces and connections between the coast and the city should be planned to support cooling air circulation.
- **Antalya Cool Roof Programme—Implementation Guide:** Relevant institutions should prepare a "Cool Roof Implementation Guide" tailored to Antalya's hot and humid climate. It should identify suitable materials, construction details and cost–benefit assessments for existing roof types, including flat roofs, pitched tiled roofs and roof terraces. The proposed minimum values for new buildings are solar reflectance ≥ 0.65 and a solar reflectance index (SRI) ≥ 78. Research indicates that cool roofs can reduce indoor temperatures in buildings without air conditioning by 1.2–3.3°C, with this effect expected to become increasingly important as the climate crisis intensifies. The guide should be implemented widely through integration with Antalya Metropolitan Municipality's existing building renovation programmes [8, 9, 10].
- **A Mediterranean-specific green roof design and installation standard:** Green roof maintenance and irrigation requirements under Mediterranean summer drought conditions differ from those in northern Europe. Mediterranean studies indicate that green roofs can reduce summer cooling loads by 9.6–15.1%, with reductions reaching 36.8% when green roofs and green façades are combined. Innovative green roof systems using biochar-amended substrates have been documented to reduce roof surface temperatures by 9.8°C compared with conventional roofs [11, 12]. Standard details for minimally irrigated green roofs using drought-tolerant species should be developed for Antalya's climate. Feasibility assessments based on substrate type and structural capacity should be systematically incorporated into permitting.
- **Continuity of shade in public spaces—architectural shading standards:** Architectural design standards should establish minimum shade continuity for school grounds, healthcare facility entrances, pedestrian areas and transport hubs. They should set a target of at least 70% of walking surfaces being shaded during peak solar hours, from 10:00 to 16:00. The selection of shading elements, including brise-soleil, light-transmitting photovoltaic panels, pergolas and trees, should jointly consider thermal comfort, ease of maintenance and potential combined flood and storm

loads. The distribution of shaded public spaces should be overlaid with heat vulnerability maps to identify priority intervention areas [2, 10].

- **Urban tree planting—integration into architectural projects and species standards:** Tree planting should be an integral part of architectural design as well as landscape design. Relevant institutions should establish standards requiring surrounding tree shade to be included in building solar control calculations, adequate soil profiles and drained rooting volumes in parking and open space layouts, and safe distances between tree roots, building foundations and utility lines to be shown on architectural drawings. A local species guide should also be developed collaboratively to encourage native, low-water-demand trees suited to Antalya's dry summers and capable of mitigating urban heat, such as Mediterranean oak, olive, mulberry and Anatolian black pine [2, 10].

3.1.4. Conclusion

The central conclusion concerning urbanisation, spatial planning and climate resilience is that climate risks in Antalya should be recognised as a primary determinant of land-use decisions. Climate-risk-sensitive planning can reduce the creation of new risks, progressively lower existing risks, improve public open space quality, direct infrastructure investment more effectively and strengthen post-disaster recovery capacity. This transformation is an environmental objective and a matter of public interest, sound urban development and social justice.

3.2. Retrofitting the Existing Building Stock for Disaster Resilience

3.2.1. Scope and Current Situation

A substantial part of Türkiye lies within an active seismic zone. The loss of life and property in past earthquakes has made it necessary to reassess disaster risks in the existing building stock. Many buildings predate current seismic regulations and do not fully meet the performance and safety criteria of the Turkish Building Earthquake Code (TBDY 2018). Changes of use, unauthorised alterations, inadequate maintenance and unsupervised renovations can further compromise building safety.

Creating disaster-resilient cities requires a scientifically grounded inventory of existing buildings, the identification of risk levels, and the planning of necessary retrofitting or regeneration measures. Building safety is now assessed alongside energy efficiency, environmental sustainability and climate adaptation, which are fundamental components of regeneration processes.

An examination of practices in Antalya's urban regeneration areas indicates that energy efficiency and bioclimatic design objectives are overlooked in many retrofitting and reconstruction projects. Compliance of replacement buildings with current BEP-TR classifications is not systematically checked.

In Antalya, rapid urbanisation, intensive migration, seasonal population growth and historical gaps in inspection make an up-to-date assessment of the building stock particularly important. The city's exposure to seismic hazards, high temperatures and humidity, together with high energy consumption, necessitates an integrated approach to building safety and energy efficiency.

3.2.2. Identification of Problems

- A substantial proportion of existing buildings were constructed under earlier seismic regulations.
- Up-to-date, comprehensive building inventories are absent or insufficient across Antalya.

- Buildings constructed before 2000 commonly exhibit low concrete strength, inadequate reinforcement detailing, soft-storey irregularities and deviations from approved designs.
- Unauthorised construction and past zoning amnesties have created uncertainties concerning building safety.
- Some buildings received inadequate engineering and inspection services during construction.
- Unauthorised renovations, changes of use and alterations to structural systems adversely affect building performance.
- Inadequate maintenance and repair reduce structural capacity.
- Rapid screening and performance assessments for identifying at-risk buildings have not been implemented widely enough.
- High retrofitting costs lead owners to postpone necessary interventions.
- Existing buildings perform poorly in energy efficiency, water efficiency and climate adaptation.
- Technical, financial and administrative support mechanisms for retrofitting and regeneration are insufficient.
- Architectural approval for buildings demolished and reconstructed through urban regeneration focuses on structural and zoning compliance, without assessing climate performance, orientation or passive design.
- Historic buildings, particularly the traditional urban fabric of Kaleiçi and Muratpaşa, lack an integrated framework combining architectural heritage conservation with climate adaptation during retrofitting or regeneration.
- Retrofitting projects are often restricted to basements and structural interventions, without concurrent upgrades to external walls, roofs and windows in line with TS 825:2024.
- The coordinating role of the project architect is not clearly defined in building regeneration, potentially excluding architects from the coordination of retrofitting projects.

3.2.3. Proposed Solutions

- A comprehensive building stock inventory should be established across Antalya, and the Antalya Earthquake Master Plan should be completed.
- Rapid screening, performance assessments and detailed engineering investigations should be expanded to identify at-risk buildings.
- Area-based retrofitting and regeneration programmes should prioritise buildings according to risk.
- Decisions to retrofit or reconstruct should jointly consider technical, economic and social criteria.
- Engineering solutions such as reinforced concrete jacketing, steel strengthening, carbon fibre-reinforced polymer applications, additional shear walls and ground improvement should be used more widely.
- Qualified engineers should prepare and review retrofitting projects based on seismic performance assessments, material testing and geotechnical investigations.
- Financial support mechanisms should include low-interest loans, long-term financing, tax and fee reductions, and insurance incentives.

- Local authorities should provide technical advice and guidance to residents.
- Retrofitting and regeneration should incorporate energy efficiency and climate adaptation objectives.
- Thermal insulation, renewable energy systems, water efficiency solutions and environmentally sound building materials should be encouraged.
- Green building practices and low-carbon development should be supported.
- Institutional cooperation among central government, local authorities, universities, public institutions, professional chambers and civil society organisations should be strengthened.
- Education and awareness initiatives should improve public understanding of building safety, disaster risks and retrofitting.
- **Mandatory integrated architectural projects in urban regeneration:** All retrofitting and reconstruction projects concerning buildings identified as at risk should require an "Integrated Architectural Regeneration Project" as a condition of permitting. Prepared concurrently with the structural intervention design, it should cover building envelope upgrades, including TS 825:2024-compliant insulation, windows and roofs, renewable energy integration and bioclimatic orientation decisions. The project should be prepared by the project architect and reviewed and endorsed by the Chamber of Architects [1, 7].
- **Climate-adaptive conservation guidelines for Antalya's traditional buildings:** An "Antalya Historic Building Stock Climate Adaptation Guide" should define interventions that improve energy efficiency and climate resilience while preserving the original architectural character and designated heritage values of traditional buildings in Kaleiçi, Muratpaşa and other historic neighbourhoods. It should address recyclable and climate-adapted materials, supplementary insulation techniques that preserve original façade elements, and solar energy systems adapted to historic roof structures [1].
- **Building typology mapping and regeneration priorities:** Alongside the Chamber of Civil Engineers' structural risk inventory, the Chamber of Architects should prepare an "Architectural Typology Map" documenting predominant building types across Antalya's neighbourhoods by construction period, façade type, number of storeys and building form. The map should identify typologies with the lowest energy performance and areas where systematic façade renovation would have the greatest aggregate impact, providing a concrete architectural basis for investment prioritisation [1, 7].

3.2.4. Conclusion

Retrofitting existing buildings for disaster resilience is essential to safeguarding life and property and creating sustainable, resilient cities. Establishing Antalya's building inventory, identifying at-risk buildings through scientific methods and implementing retrofitting or regeneration programmes in priority areas are therefore crucial. Success requires cooperation among central government, local authorities, universities, professional chambers and all relevant stakeholders. Integrating building safety with energy efficiency and climate adaptation will make an important contribution to a safer, more sustainable and disaster-resilient Antalya.

3.3. Implementing Risk-Based Urban Regeneration

3.3.1. Scope and Current Situation

Extreme weather events driven by the global climate crisis, including floods, severe storms and forest fires, together with geological disasters such as earthquakes, threaten cities' socioeconomic infrastructure with irreversible damage. Building resilience to earthquake hazards, which present the greatest risk of loss of life and property among these threats, is a fundamental component of global sustainable development objectives. The prompt implementation of urban regeneration strategies to adapt existing buildings to climate and disaster risks is therefore a national and local imperative.

In Antalya, situated within the Mediterranean Basin's vulnerable ecosystem, intensive migration after 1950 and uncontrolled tourism-led growth between 1970 and 1990 left a legacy of unplanned development. The city, whose central population now approaches three million, continues to grow rapidly. While its central residential areas have relatively modern standards, districts forming its historic core face multiple climate risks. Although local authorities and the Housing Development Administration of Türkiye (TOKİ) have jointly implemented various urban regeneration projects, mechanisms for an integrated, citywide approach to climate and disaster resilience remain insufficiently developed.

3.3.2. Identification of Problems

The following fundamental and persistent problems have been identified in urban regeneration processes:

- **Lack of an area-based strategy and climate vision:** A comprehensive urban regeneration vision informed by disaster risks and climate scenarios has not been established at the strategic level. Existing workshops and local planning processes have not translated into concrete, results-oriented action to identify priority and at-risk areas at district and neighbourhood scales.
- **Insufficient interinstitutional coordination and data sharing:** Urban regeneration reports produced by professional chambers and civil society, which provide a scientific evidence base, are not adequately consolidated by local decision-making authorities. Institutional unresponsiveness prevents the establishment of multistakeholder governance.
- **Parcel-based approaches and loss of ecological infrastructure:** Regeneration at parcel level, rather than block or neighbourhood level, reduces the process to demolition and reconstruction. This erodes ecological infrastructure, community facilities and urban green corridors, turning cities into carbon-intensive "concrete islands".
- **Property rights and transparency:** A people-centred approach and the protection of property rights are cornerstones of sustainable regeneration. In practice, the majority rule based on land ownership shares under Law No. 6306 can favour financially powerful actors and leave minority owners vulnerable. The absence of interim injunctions in legal proceedings can lead to irreparable property losses and substantial financial and legal compensation liabilities for public authorities.
- **Gentrification and social vulnerability:** Substantial increases in property values generated by projects can displace existing, socioeconomically disadvantaged rights holders, particularly low-income groups, leading to urban displacement and social segregation.

3.3.3. Proposed Solutions

The following measures should be implemented to address these problems and establish risk-based, equitable and sustainable urban regeneration:

- **Fit-for-purpose land management and integrated planning:** Urban regeneration should adopt an interdisciplinary, GIS-based land management model that extends beyond a narrow focus on ownership. Projects should be designed at a minimum of block or neighbourhood scale, with carbon neutrality and green infrastructure as core objectives.
- **An urgent action agenda:** Disaster dynamics and the climate crisis continue to advance without waiting for preventive action. Cities have no time to lose in risk reduction and regeneration. Earthquake risk mitigation measures should be implemented promptly, and urban resilience investments and regeneration projects should be prioritised under an "Emergency Action Plan" without bureaucratic delays.
- **Socially oriented and transparent implementation:** Rights-holder arrangements and development rights should be defined fairly and transparently at the outset. Projects should follow a bottom-up approach involving local communities, civil society and academic stakeholders.
- **Equitable sharing of development gains and land value uplift:** Increases in urban land and property values arising from the rehabilitation of at-risk areas should be distributed fairly in the public interest and reinvested as a revolving source of finance for urban resilience funds.
- **Legislative reform centred on property rights:** Law No. 6306 and related urban regeneration legislation should be revised to safeguard property rights, minority rights and social justice while maintaining a balance between the public interest and individual rights.
- **Continuity of implementation:** Following project completion, environmental, social and economic impacts should be continuously monitored. Plans should be updated flexibly in response to climate parameters and changing urban dynamics.
- **Identification of priority areas for climate-resilient regeneration:** The ageing building stock, ecological vulnerability and persistent ownership complexities should be analysed to designate "Priority Climate-Resilient Regeneration Areas" and develop projects for them.

3.4. Data-Driven Smart City Strategies for Addressing the Climate Crisis and Disaster Risks

3.4.1. Scope and Current Situation

Rapid population growth, growing pressure from rural-to-urban migration, global socioeconomic developments and climate change are confronting cities with structural crises that are difficult to manage. Where planning processes fail to meet international standards, cities face interconnected, persistent problems, including transport difficulties, inadequate infrastructure, water stress, housing and shelter access constraints, public health risks, energy crises, environmental pollution and security weaknesses.

The search for more liveable, resource-efficient and sustainable urban environments in response to these complex twenty-first-century dynamics has brought the "smart city" concept to the forefront of global urban policy. In its most basic sense, a smart city is an integrated system in which urban services use advanced technologies and online platforms to provide residents with continuous, high-quality, accessible and affordable services.

Building urban resilience to the destructive impacts of climate change and associated disaster risks is central to the 31st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP31) and the Sustainable Development Goals, particularly SDG 11. In Türkiye, smart city initiatives are still developing at the national policy level, and the integration of national strategies with local implementation remains necessary. Action 26, included in the Ministry of Environment, Urbanisation and Climate Change's strategic planning framework and the "2020–2023 National Smart Cities Strategy

and Action Plan", aims to designate urban regeneration and development areas as "smart districts" that can serve as ecological and technological models for other developing cities.

In Antalya, a city with the potential to become a global urban centre and internationally recognised destination, historical urbanisation practices have not reached the desired level of scientific rigour and planned development. To secure a climate-resilient future, new development areas must incorporate smart city technologies from the outset. In existing built-up areas, urban regeneration integrated with smart city systems must be implemented, setting aside political disputes and expectations of speculative property gains.

3.4.2. Identification of Problems

Assessment against COP31's global climate and resilience objectives identifies the following major barriers to the effective use of smart city technologies in disaster risk reduction and climate adaptation:

- **Spatial data standards and reliability:** Significant deficiencies exist in the spatial data infrastructure underpinning smart city architecture and disaster scenarios. In projects requiring collaboration across professional disciplines, failures to update data in real time and verify its accuracy can cause decision support systems to generate erroneous outputs.
- **Interinstitutional coordination and data sharing:** Planning, coordination and communication among local authorities, central government bodies, the private sector and civil society organisations are weak. Technical knowledge and urban service information are not adequately shared. The absence of open data platforms creates institutional blind spots and duplicate investment. Failure to integrate technological infrastructure with local authorities' existing systems further undermines coordinated operations.
- **Inclusion of civil society and professional chambers:** Smart city projects designed without residents, professional chambers and other urban stakeholders fail to gain public acceptance. Solutions that residents neither use nor support become costly losses of public time and financial resources.
- **Insufficient skilled workforce capacity:** Both national and local institutions lack sufficient specialised personnel to design smart urban services, analyse big data and operate advanced systems.
- **Failure to integrate technology into decision-making:** Supply and demand assessments, market needs and urban risk forecasts rely on static, conventional, non-digital methods rather than live GIS-based data. This leaves authorities reacting to events when disasters occur.

3.4.3. Proposed Solutions

To develop Antalya into a sustainable, climate-adapted and disaster-resilient smart city of the future, the following strategic actions and international good practice examples are proposed in line with international criteria, including the Eden Strategy Institute's parameters of vision, leadership, budget, financial incentives, support programmes, innovation ecosystems and policies:

- **GIS-Based Early Warning Systems:** Geographic information systems (GIS) are essential to establishing smart cities and minimising disaster risks. By linking information and structural data to location, disaster risks, including earthquakes and climate-related hazards such as flash floods, flooding and forest fires, should be simulated across the city in real time. Analyses using these spatial data should enable authorities and emergency responders, including ambulance services,

fire brigades and search and rescue teams, to make informed decisions and identify the fastest and safest routes within seconds.

- **Identifying At-Risk Buildings through a Building Inventory:** Urban regeneration provides an opportunity to use technology to assess building resilience to disasters. AI-enabled structural health monitoring sensors should be piloted in next-generation public buildings and residential developments constructed in at-risk regeneration areas. During seismic activity or ground shaking, these systems should transmit real-time data on structural damage and fatigue in concrete and reinforcing steel to the Urban Data Centre. This would provide objective evidence to prioritise buildings during post-disaster search and rescue operations.
- **GIS-Based Open Data Platforms and Spatial Data Infrastructure:** Data are the most strategic resource of the information age and smart urbanism. All urban regeneration and disaster management systems should be built on GIS supported by fully developed spatial data infrastructure. Linking information to location enables accurate supply and demand assessments, the identification of market needs and rapid, informed decisions in at-risk areas. Local open data platforms should therefore be established immediately to ensure data continuity, currency and accuracy.
- **International Best Practice—LONDON:** London, a leading city in global smart city rankings, has committed within its strategic vision to reducing the number of people without internet access by 20% annually. Accordingly, while developing technological infrastructure to address climate-related risks, the city has adopted digital inclusion and equitable access to information as fundamental principles of its smart city initiatives.
- **International Best Practice—SINGAPORE:** Through public incentive mechanisms such as the Productivity Solutions Grant, Singapore finances up to 70% of the costs incurred by small and medium-sized enterprises (SMEs) developing smart technologies and digitalising their operations. The city successfully applies this data-driven ecosystem to smart traffic management and proactive healthcare systems. Under local smart city strategies and roadmaps, similar financial incentives and subsidies should support local start-ups and SMEs developing seismic risk reduction and climate adaptation technologies.
- **A Smart City Vision and Civil Society:** The smart city of the future should establish an interactive governance model that enables every resident to participate actively in decision-making. Dedicated boards or committees within city administrations should oversee this process through research and development. In smart city and urban regeneration projects, implementing authorities should establish institutional and legal partnerships with universities, the private sector and civil society organisations as providers of scientific evidence and urban technical expertise.
- **Pilot Smart Districts and Modular Regeneration:** Urban regeneration offers important opportunities to implement smart city approaches on the ground. As at-risk buildings are replaced with structures resilient to disasters and the climate crisis, these areas should be equipped with smart grids, energy-efficient systems and GIS-integrated infrastructure and designated as pilot smart districts. Feedback and data from these small-scale areas would provide an evidence base for citywide deployment.
- **Skilled Personnel and Training Programmes:** Recognising that technological tools alone are insufficient, specialised training should strengthen the skills of administrative and technical personnel involved in urban service development. In parallel, digital skills and behaviour-change

training should be expanded through neighbourhood councils to improve residents' access to information and communication technologies and enable their use in disaster risk reduction.

3.4.4. Conclusion

Antalya's future requires both investment in physical infrastructure and a data-driven, participatory, technology-enabled and climate-resilient approach to urban governance. As the climate crisis intensifies and extreme weather events become more frequent and severe, smart city applications have become a strategic necessity for reducing disaster risks, managing resources efficiently and improving urban quality of life.

The smart city approach enables proactive governance centred on identifying risks in advance and reducing losses. Through GIS, sensor networks, AI-enabled analysis, open data platforms and digital participation mechanisms, cities can anticipate climate-related threats more accurately and base decisions on scientific evidence.

Accordingly, Antalya should prioritise stronger spatial data infrastructure, improved interinstitutional data sharing, real-time disaster risk monitoring, the integration of smart city principles into urban regeneration and active public participation in decision-making. Planning new development and regeneration areas as smart districts would substantially strengthen the city's resilience to future climate and disaster risks.

Antalya's development into a global city that adapts to climate change, withstands disasters, uses resources efficiently and offers a high quality of life depends on the sustained implementation of an integrated smart city vision combining technology, data, scientific knowledge and participatory governance. This transformation is a strategic imperative for sustainable development, social well-being and the security of future generations, as well as a process of technological modernisation.

3.5. Resilience of Transport Systems

3.5.1. Scope and Current Situation

Transport is one of the city's most critical infrastructure systems in the face of climate change and disasters. Extreme precipitation, flooding, heatwaves, forest fires, landslides and coastal flooding can directly affect roads, bridges, junctions, underpasses, public transport and emergency access routes. Transport planning should therefore be regarded as strategic resilience planning that supports emergency access, evacuation, logistics and essential service continuity, alongside daily mobility needs.

During disasters, transport continuity is vital for search and rescue, casualty evacuation, humanitarian assistance and the continuation of critical public services. Transport network resilience depends on alternative routes, intermodal integration and logistical planning capacity, as well as the physical robustness of infrastructure.

Transport functionality should therefore be maintained throughout the mitigation, preparedness, response and recovery phases of disaster management. Emergency transport corridors, alternative routes, logistics centres and connections between transport modes are fundamental components of disaster-resilient transport planning.

Rail systems are particularly important during disasters because of their high capacity, relatively limited sensitivity to weather conditions and operational reliability. When roads are damaged or inaccessible, rail can provide a critical alternative for moving relief supplies and people.

The principal urban planning objective is to establish an integrated transport system that reduces car dependency, strengthens public transport, supports walking and cycling, safeguards access to critical

services and provides alternative transport options during disasters. Low-carbon transport and disaster resilience are complementary policy objectives that should be addressed together.

3.5.2. Identification of Problems

- Dependence on road transport is high, while alternative routes and transport modes remain insufficiently developed.
- Underpasses, stream crossings and low-lying transport links exposed to flooding, extreme precipitation and coastal flooding threaten transport continuity.
- The disaster resilience of critical bridges, viaducts and transport infrastructure is inadequate in some areas.
- Emergency access and evacuation routes for hospitals, fire stations, emergency assembly areas, logistics centres and tourism areas are insufficiently defined or lack integrated planning.
- Integration with alternative transport modes for disaster response, including rail, maritime transport and aviation, is limited.
- Planning for logistics hubs and transfer centres for storing and distributing relief supplies is inadequate.
- Public transport, pedestrian and cycling infrastructure are insufficient in terms of both accessibility and thermal comfort.
- Shaded stops, continuous pedestrian connections, cycling networks and urban design measures that reduce heat stress are not widely available.
- Electric mobility infrastructure and energy infrastructure are insufficiently integrated with spatial planning.
- Increased tourism-season mobility and disaster evacuation requirements are not assessed together, potentially intensifying transport pressures, particularly in coastal areas.

3.5.3. Proposed Solutions

- Main transport corridors, bridges, junctions, underpasses and critical access networks should be tested against climate change and disaster scenarios through transport continuity assessments.
- Critical bridges, viaducts and transport infrastructure should be strengthened to improve disaster resilience.
- Priority emergency transport corridors should be designated for AFAD, fire services, healthcare teams and other emergency responders, and their continuous accessibility should be ensured.
- Secondary and tertiary alternative routes should be identified in advance and regularly updated for use when main roads become unavailable.
- Intermodal systems incorporating rail, maritime transport and aviation should be developed to provide alternative access during disasters.
- Logistics centres and transfer points should be located in safe areas for storing and distributing relief supplies.
- New development and urban regeneration areas should follow transit-oriented development, mixed-use planning and pedestrian and cycling accessibility principles.

- Public transport should be strengthened, and pedestrian and cycling networks should be continuous and safe.
- Shading, tree planting, permeable surfaces and cooling public space measures should be expanded around stops, interchanges, schools and healthcare facilities.
- Electric vehicle charging infrastructure, electric public transport and renewable-energy-supported transport solutions should be integrated into zoning and transport plans.
- Seasonal mobility management plans should be prepared for coastal and tourism areas, jointly assessing public transport, maritime transport, parking management and evacuation scenarios.
- Emergency access routes and evacuation corridors should be integrated into digital maps and disaster management systems and kept up to date.

3.5.4. Conclusion

Strengthening transport resilience to climate change and disasters requires integrated planning across land use, settlement patterns, energy infrastructure, disaster management, logistics and public services, alongside improvements to existing roads. Establishing a disaster-resilient, low-carbon, accessible and sustainable transport system in Antalya would support the continuity of urban life and make a significant contribution to disaster preparedness and climate adaptation.

3.6. Energy and Infrastructure

3.6.1. Investment in Disaster-Resilient Infrastructure

3.6.1.1. Scope and Current Situation

Utility and infrastructure systems, including energy, water supply, sewerage, stormwater drainage, communications, transport and waste management, are among the urban components most vulnerable to climate change. Heatwaves increase energy demand, while extreme precipitation and flooding strain drainage, sewerage and transport infrastructure. Fires and storms threaten power transmission lines and communications systems. Infrastructure investment should therefore be assessed in conjunction with multiple disaster risks and spatial development decisions, alongside technical capacity requirements.

The principal urban planning responsibility is to incorporate spatial decisions concerning critical infrastructure siting, protection zones, capacity alignment with development areas, renewable energy sites, microgrid opportunities, electric mobility infrastructure and disaster-related service continuity into plans.

3.6.1.2. Identification of Problems

- **Disconnect between infrastructure capacity and planned densities:** Population and land-use intensification resulting from plan amendments are frequently assessed without considering stormwater, sewerage, drinking water, energy and transport capacity.
- **Lack of multihazard assessments for critical infrastructure:** Substations, power lines, pumping stations, treatment plants, communications infrastructure and emergency service facilities require integrated assessment of flood, fire, heat and coastal risks.
- **Vulnerability of energy infrastructure to climate risks:** Extreme heat, storms, fires and flooding can interrupt electricity services, with critical consequences for healthcare, disaster management, water supply, transport and communications.

- **Insufficient incorporation of renewable energy and microgrids into planning:** Rooftop solar PV, energy generation in public buildings, energy storage, electric vehicle charging and microgrids remain fragmented when unsupported by planning decisions.
- **Inadequate shared databases and interinstitutional coordination:** Investment priorities cannot be reliably established when infrastructure networks, vulnerable locations, capacity constraints and planning decisions are not monitored through shared GIS infrastructure.

3.6.1.3. Proposed Solutions

Investment in Disaster-Resilient Infrastructure and Critical Infrastructure Risk Assessment

- **Critical infrastructure inventory:** Critical facilities and networks for energy, water supply, sewerage, stormwater, communications, transport and waste management should be inventoried in GIS.
- **Multihazard risk matrix:** Critical infrastructure should be classified according to exposure to flooding, coastal flooding, fire, heatwaves, earthquakes, landslides and infrastructure failure, and priority areas for strengthening should be identified.
- **Alignment between planning decisions and capacity:** New development areas and density-increasing plan amendments should be assessed alongside capacity analyses obtained from the relevant infrastructure agencies. Density increases should not be approved where capacity is insufficient.
- **Protection zones and continuous access:** Planning provisions should establish access, security, flood protection and fire risk requirements around critical facilities such as substations, pumping stations, treatment plants, fire stations and disaster logistics sites.

Energy-Resilient Urban Infrastructure

- **Strengthening electricity infrastructure against climate risks:** Power transmission and distribution systems should be assessed against fire, extreme heat, storm and flood risks, and critical potential outage points should be identified.
- **Energy continuity for public facilities and disaster centres:** Backup power and renewable-energy-supported systems should be planned for hospitals, fire stations, disaster coordination centres, water pumps, communications centres and temporary shelters such as schools and sports halls.
- **Renewable energy integration:** Plan provisions and implementation guides should support solar energy use on public buildings, parking areas, public transport facilities, marketplaces and suitable roof surfaces.
- **Microgrid and energy storage sites:** Priority public sites, utility areas and facility locations for microgrids that maintain services during disasters should be identified during planning.
- **Coordination with electric mobility infrastructure:** Charging infrastructure for electric buses, shuttle services, taxis and private vehicles should be addressed jointly with transport planning and energy infrastructure capacity.

3.6.1.4. Conclusion

Urban planning contributes to energy and infrastructure resilience by coordinating infrastructure investment with spatial development decisions. Addressing critical infrastructure risk assessments, renewable energy integration, microgrid opportunities, coastal adaptation and water-sensitive urban design together will

enhance Antalya's climate adaptation capacity, strengthen service continuity during disasters and improve investment prioritisation. Detailed feasibility assessment is beyond the scope of this text, as investment costs vary according to site size, existing infrastructure, ground and hydrological conditions, implementation methods and interinstitutional coordination.

3.6.2. Water-Sensitive Urban Design and Flood Risk Management

3.6.2.1. Scope and Current Situation

Climate change exposes Antalya to both drought and water stress and flooding caused by short-duration, high-intensity precipitation. Expanding impervious surfaces, disrupted natural drainage and inadequate infrastructure in some areas accelerate runoff generation and increase urban flood risk.

Stormwater management should therefore adopt a water-sensitive city approach based on retention, storage, groundwater recharge and controlled conveyance, alongside conventional drainage. The disaster resilience of water and energy infrastructure should also be assessed together with flood management, coastal protection, green infrastructure and sustainable water use.

Recent flooding in Antalya demonstrates the need to reassess existing drainage systems under changing climatic conditions. The city's topography, intensive development pressure, narrowing natural drainage corridors and expanding impervious surfaces constitute key vulnerabilities that may further increase future flood risk.

The Water Sensitive Cities approach treats stormwater as a component of urban ecosystems and climate adaptation. In cities such as Antalya, exposed to both flash flooding and drought-related water scarcity, key planning objectives should include stormwater retention, groundwater recharge, runoff reduction, water reuse and stronger blue–green infrastructure. Protecting the urban water cycle requires an integrated approach combining flood management with sustainable water resource use.

3.6.2.2. Identification of Problems

- Existing stormwater drainage systems may be inadequate under increasing rainfall intensities and climate change scenarios.
- Flood risk is high in underpasses, low-lying roads, stream crossings and densely built-up areas.
- Urbanisation and expanding concrete surfaces reduce natural drainage pathways and rainwater infiltration capacity.
- Increasing impervious surface coverage intensifies runoff and flash flooding.
- Flood conveyance corridors and floodplains have historically been subject to development pressure.
- Stormwater management relies predominantly on localised infrastructure solutions rather than catchment-scale approaches.
- Water and energy infrastructure lack sufficient resilience to flooding, earthquakes, fires, extreme temperatures and storms.
- Facilities supporting critical public services have limited alternative energy and water supply systems.
- Rainwater harvesting is not widely practised and remains underused in existing buildings.
- Sea-level rise, coastal erosion and storm surge risks are insufficiently incorporated into coastal infrastructure planning.

- Design reference elevations used in development control are insufficiently linked to flood risk assessments.
- Basements and ground floors in flood-prone areas may be designed in ways that leave them exposed to inundation.
- Green infrastructure and permeable surfaces have not been sufficiently adopted across the city.
- Catchment- and subcatchment-scale stormwater management is insufficiently integrated into planning.
- Development pressure impairs the functioning of stream channels, flood corridors and natural drainage systems.
- Natural infiltration areas supporting groundwater recharge are declining.
- Blue–green infrastructure has not been planned as an integrated citywide network.
- Rainwater use, greywater systems and water reuse remain limited.
- Water-intensive landscaping exacerbates drought risks.

3.6.2.3. Proposed Solutions

- Stormwater drainage systems should be redesigned to account for climate change scenarios, extreme precipitation projections and future development conditions.
- Hydraulic capacity assessments should identify priority infrastructure renewal and rehabilitation programmes in high-risk areas.
- Catchment-scale rainfall–runoff modelling should support integrated flood management.
- Stream channels, natural drainage corridors and floodplains should be protected, and new development in these areas restricted.
- GIS-based flood risk maps should be incorporated into planning and permitting.
- Detention basins, flood storage areas, backflow prevention systems and flow control structures should be established in critical locations.
- Water-sensitive urban design principles should become mandatory in new development and urban regeneration areas.
- Rainwater harvesting systems should be expanded in public buildings, tourism facilities, industrial areas and large residential developments.
- Harvested rainwater should be used for landscape irrigation, cleaning, firefighting reserves and, where appropriate, in conjunction with greywater systems.
- Minimum permeable surface ratios should be specified in implementation zoning plans and progressively increased.
- Permeable paving should be expanded in parking areas, squares, pavements and open spaces.
- Green infrastructure, including rain gardens, bioswales, green roofs, shaded pedestrian routes and natural drainage systems, should be supported.
- Backup power, alternative supply lines, remote monitoring and automation should be developed for water and energy infrastructure.

- Hospitals, disaster coordination centres, fire stations, drinking water systems and shelter facilities should be included in priority resilience programmes.
- Coastal protection and adaptation strategies should account for sea-level rise, flooding and erosion.
- Design grading plans based on scientific flood modelling should be prepared for flood-prone areas and made mandatory in permitting.
- Municipal zoning regulations should include binding provisions governing development in flood-prone areas.
- Stormwater should be managed at catchment and subcatchment scales, with stream systems, flood corridors and natural drainage networks serving as fundamental planning inputs.
- Water-sensitive city design principles should be mandatory planning criteria in new development and urban regeneration areas.
- Minimum permeable surface ratios should be established for parking areas, squares, pedestrian routes, residential development open spaces and public areas and incorporated into plan provisions.
- Stormwater retention measures, including rain gardens, bioswales, infiltration areas, rainwater storage tanks and detention basins, should be expanded.
- Stream corridors and floodplains should be protected to establish an interconnected citywide blue–green infrastructure network.
- Urban open and green spaces should be designed as climate adaptation infrastructure that retains, stores and conveys water, alongside their recreational functions.
- Measures that increase groundwater recharge should be encouraged, and natural infiltration areas that reduce runoff should be protected.
- Greywater and rainwater reuse systems should be expanded in new buildings and large facilities.
- Drought-tolerant plants, smart irrigation and water-efficient landscape design should be encouraged.

3.6.2.4. Conclusion

Water-sensitive urban design and flood risk management are fundamental policy areas for strengthening Antalya's climate adaptation capacity. Recognising stormwater as a valuable resource, protecting the natural water cycle, reducing flood risks and strengthening critical infrastructure resilience should be addressed together. Integrating water management, land use, infrastructure planning and disaster management can enable Antalya to become more resilient to both flooding and drought while improving sustainability and liveability.

Flood management, rainwater harvesting, groundwater recharge, blue–green infrastructure and water-efficient urban design should be considered jointly to enhance Antalya's climate adaptation capacity. Integrating the water-sensitive city approach into planning and implementation will strengthen resilience to both flood and drought risks.

3.6.3. Climate Adaptation in Coastal Cities

3.6.3.1. Scope and Current Situation

Antalya's coastal setting creates particular sensitivity to climate change. Sea-level rise, coastal flooding, coastal erosion, storm surges and wave action directly affect the use and safety of coastal areas. Coasts

should therefore be assessed comprehensively in terms of ecological connectivity, public access, disaster safety and critical infrastructure protection, alongside tourism and recreation.

Antalya has developed on travertine cliffs that constitute one of the Mediterranean Basin's most distinctive coastal systems. This geomorphological structure gives the coast its character while creating vulnerabilities to climate change and geological processes. Wave erosion at cliff bases, disrupted groundwater drainage and regional seismic activity can cause cliff deformation and mass movements.

Coastal deformation poses significant safety risks to buildings, tourism facilities and public spaces on cliff tops. Future coastal planning should therefore integrate climate impacts, geological risks and disaster management.

3.6.3.2. Identification of Problems

- Sea-level rise, coastal flooding, storm surges and coastal erosion are insufficiently integrated into spatial planning.
- Scenario-based coastal risk zones for climate impacts are inadequately defined.
- Wave erosion, drainage problems and seismic activity increase deformation and landslide risks along Antalya's cliffs.
- No continuously operating system provides regular, integrated monitoring of coastal deformation.
- Cliff-top development has occurred without adequate consideration of geological vulnerability and deformation risks.
- Intensive tourism uses, infrastructure and public activities in coastal areas are not jointly assessed with disaster risks.
- Emergency access and evacuation plans for coastal roads, beaches, port surroundings and tourism areas are inadequate.
- Coastal protection can prioritise engineered structures over nature-based solutions.
- Planning approaches insufficiently integrate coastal ecosystem conservation and public access.

3.6.3.3. Proposed Solutions

- Scenario-based coastal risk zones should account for sea-level rise, coastal flooding, erosion and storm impacts and be incorporated into zoning plans.
- New buildings, land reclamation, tourism facilities, parking areas and utility infrastructure along the coast should be restricted or reassessed according to risk zones.
- Adaptation strategies for each coastal segment should combine retreat, accommodation, nature-based protection and appropriately controlled engineering measures.
- Public access, continuity of open spaces and coastal ecosystem conservation should become core planning considerations.
- Emergency access and evacuation scenarios should be developed for coastal roads, ports, beaches, tourism areas and intensively used locations.
- A continuously operating "Integrated Coastal Monitoring System" should be established along Antalya's cliffs.

- Global navigation satellite system (GNSS) stations, interferometric synthetic aperture radar (InSAR) and light detection and ranging (LiDAR) systems should continuously monitor cliff deformation, subsidence and displacement.
- Satellite imagery and remote sensing should support regular analysis of coastal deformation and updates to risk maps.
- Uncrewed aerial vehicles and LiDAR should generate three-dimensional cliff models to enable early identification of potential rockfalls and mass movements.
- Coastal protection zones and building setback lines should be redefined according to the geological vulnerability of the cliffs.
- Buildings in areas with critical deformation risks should receive priority in urban regeneration programmes.
- Development should be removed from at-risk coastal areas, which should be repurposed as green corridors, recreational spaces and ecological buffer zones.

3.6.3.4. Conclusion

Coastal climate adaptation requires an integrated assessment of sea-level rise, coastal flooding, erosion, cliff deformation and disaster risks alongside land use, development, tourism, infrastructure and ecological values. In Antalya, protecting travertine cliffs, scientifically monitoring coastal deformation and implementing risk-based coastal planning are essential to safeguarding people and preserving the city's natural and cultural coastal identity for future generations. Integrated coastal adaptation strategies will contribute substantially to Antalya's development as a climate-resilient and sustainable coastal city.

3.7. Health and Disaster Management

3.7.1. Community-Based Disaster Resilience—Disaster Preparedness Training

3.7.1.1. Scope and Current Situation

Community-based disaster resilience emphasises that disaster management requires shared responsibility among individuals, local authorities, civil society organisations and the private sector, alongside government institutions.

In Türkiye's disaster management framework:

- Disaster preparedness training is delivered through schools, public institutions and civil society organisations.
- Basic protective actions, including "drop, cover and hold on", sheltering in place, "brace yourself and lie down", and evacuation, are taught.
- Various institutions, particularly AFAD, conduct awareness-raising activities.
- International good practices from the Federal Emergency Management Agency (FEMA), the American Red Cross and the National Weather Service inform basic protective-action training.
- Disaster policies are guided by international strategies such as the Sendai Framework for Disaster Risk Reduction and the Hyogo Framework for Action.

Nevertheless, existing training remains predominantly focused on information provision and does not adequately develop practical skills or sustained behavioural change.

3.7.1.2. Identification of Problems

- Disaster preparedness training lacks a sufficiently systematic and standardised national framework.
- Training is predominantly theoretical, with limited emphasis on practical skills and protective behaviours.
- Coordination among local authorities, civil society organisations and central government is insufficiently integrated.
- Disaster awareness programmes lack continuity and are largely concentrated in post-disaster periods.
- Shared, appropriate standards for protective action are not yet firmly established across society.
- Trainer preparation and the quality of training materials are insufficiently monitored.
- Local mutual support networks and neighbourhood-level organisation are weak.
- Disaster management arrangements, including the Türkiye Disaster Response Plan (TAMP) and Provincial Disaster Risk Reduction Plans (İRAP), have not been adequately translated into community-level practice.
- Disaster awareness is not embedded in the education system as a continuous process beginning in early childhood.
- Sustained disaster awareness content in the media and on digital platforms is limited.

3.7.1.3. Proposed Solutions

- Disaster preparedness training should be standardised nationally and made skills-based.
- Regular drills should make basic protective actions, such as “drop, cover and hold on”, habitual responses.
- An integrated disaster management network should connect local authorities, civil society organisations and the private sector.
- Local disaster mutual support networks should be established at neighbourhood and institutional levels.
- A certified and supervised train-the-trainer system should be developed.
- Mandatory disaster awareness education should be introduced into school curricula from an early age.
- Shared standards for protective action should be established and disseminated across society.
- Media, social media and digital platforms should be used continuously for disaster communication.
- Disaster management plans, including TAMP and İRAP, should be translated into practical local-level measures.
- Disaster resilience should be addressed comprehensively across its physical, social, economic and environmental dimensions.
- Cities should be planned according to disaster-resilient urban development principles, and building inspections should be strengthened.
- International good practices, including those of FEMA and the Red Cross, should be adapted to local systems.

3.7.1.4. Conclusion

Community-based disaster resilience requires a system founded on education, awareness and behavioural change, alongside response capacity.

Reducing disaster risks in Türkiye requires:

- Standardised training;
- Stronger interinstitutional coordination;
- Expanded local mutual support networks; and
- Sustained disaster awareness across all segments of society.

A disaster-resilient society depends on an integrated disaster management system that connects individual awareness with institutional capacity.

3.7.2. Water Pollution

3.7.2.1. Scope and Current Situation

With its abundant water resources, distinctive karst hydrology and sensitive Mediterranean ecosystem, the Antalya Basin is one of Türkiye's most important regions in environmental, agricultural and tourism terms. However, the basin currently faces a deepening water quality crisis at the intersection of global climate change and anthropogenic (human-induced) pressures. Antalya is simultaneously contending with severe drought and declining river flows, alongside infrastructure failures and flooding caused by sudden, extreme precipitation characteristic of a changing climate.

Seawater quality, which underpins the tourism economy, is monitored in accordance with international standards. As of 2025, Antalya maintains its leading position both globally and nationally, with 233 Blue Flag beaches, 13 tourism boats and 6 marinas[1]. For a city hosting approximately 40% of Türkiye's 577 Blue Flag beaches, protecting coastal waters is a matter of macroeconomic security[3]. Accordingly, Antalya Metropolitan Municipality and the Antalya Water and Wastewater Administration (ASAT) invested TRY 5.96 billion in wastewater infrastructure between 2019 and 2025. Across 36 wastewater treatment plants, an average of 770,000 cubic metres of wastewater per day underwent biological treatment[5].

The following table summarises Antalya's share of Türkiye's Blue Flag awards and the capacity of its tourism infrastructure:

Category	Türkiye Total (2025)	Antalya (2025)	Antalya's Share (%)
Blue Flag Beaches	577	233	≈ 40.3
Marinas	29	6	≈ 20.6
Tourism Boats	18	13	≈ 72.2

Despite these investments and achievements, climate-related extreme weather events threaten the city's wastewater management and seawater quality. In February 2024, Kepez and Muratpaşa received 330 millimetres of rainfall within 12 hours, equivalent to the region's average rainfall over three months, highlighting the destructive scale of flooding[6]. In districts under intense development pressure, such as Konyaaltı, urbanisation has resulted in the loss of 48.75 kilometres of stream networks, 24 hectares of wetlands and 82 hectares of coastal ecosystems, eliminating the capacity of natural blue–green infrastructure to attenuate runoff[8].

Within the Boğaçay and Sarısu flood risk area alone, impervious surfaces cover 1,038.88 hectares, preventing surface water from infiltrating into the ground and dramatically increasing the runoff coefficient[8]. This causes floodwater to enter combined sewer systems, necessitating bypasses at wastewater treatment plants when their capacity is exceeded and resulting in the discharge of partially treated or untreated wastewater into the sea. Consequently, temporary episodes of seawater pollution, characterised by foaming, elevated microbial loads and odour, directly threaten Blue Flag status.

In terms of agricultural pollution, Antalya is among the basins with the most intensive use of chemical fertilisers and pesticides in Türkiye. According to official data, approximately 4,460 tonnes of Türkiye's annual pesticide consumption, which exceeds 57,000 tonnes, are used in Antalya, placing the province second after Adana.

This intensive chemical use, reaching 14 kilograms per hectare, is compounded by the indiscriminate application of compound fertilisers containing the plant nutrients nitrogen and phosphorus[13]. Particularly in areas with intensive protected cultivation, such as Kumluca, Serik and Aksu, heavy rainfall washes these chemicals off agricultural land into surface waters, including the Aksu and Alara rivers and the watercourses feeding Düden Waterfall[15]. The findings that 65.6% of farmers are unfamiliar with the concept of the maximum residue limit (MRL), while 44.4% dispose of leftover pesticide mixtures along field margins and discard packaging into the environment, underscore the severity of non-point source pollution.

The destructive effects of pollution become more pronounced as drought reduces river flows. Climate change projections indicate that, even under optimistic scenarios, annual mean temperatures in the Antalya Basin will reach 14–16°C by the end of the century, while average relative humidity will decline from 60–66% to 62–64%, resulting in more arid conditions[19]. Standardised Precipitation Index (SPI) analyses indicate that even the Manavgat River, one of Türkiye's largest freshwater resources, faces a risk of extreme drought[21].

Combined with excessive agricultural irrigation demand, which accounts for 73.36% of total water demand, or 1,751.89 hm^3 annually[23], these pressures eliminate rivers' capacity to assimilate and dilute pollutants. Water quality studies of the Aksu River demonstrate that concentrations of heavy metal ions, including lead, copper, iron and nickel, exceed toxicity thresholds and that the affected water bodies fall within the "highly polluted water" classification.

3.7.2.2. Identification of Problems

Field investigations and scientific reports identify the following principal problems in the Antalya Basin:

- **Extreme Precipitation and Hydraulic Overloading of Wastewater Infrastructure:** Unplanned urbanisation and expanding impervious urban surfaces accelerate runoff during intense downpours. Existing combined sewer systems, which convey stormwater and domestic wastewater through the same network, and pumping stations exceed their hydraulic capacities under peak flows, such as those reaching 1,899.94 m^3/s in Boğaçay. Floodwater mixes with sewage and spreads uncontrollably into urban areas and the sea[7].
- **Environmental Threats to Blue Flag Status:** Treatment plant shutdowns during infrastructure failures and flooding, together with high agricultural and domestic pollutant loads carried by streams, cause temporary but severe microbial contamination, foaming and odour in coastal waters. Under Blue Flag criteria, these conditions lead to temporary bathing area closures and damage the destination's international tourism reputation.

- **Karst System Vulnerability and Insufficient Natural Filtration:** Karst conduits characteristic of Antalya's geology, including the Kırkgöz and Kestel swallow holes in the Döşemealtı area, transmit surface pollution directly into groundwater without natural soil filtration. Illegal industrial discharges, uncontrolled waste dumping and wastewater leakage reach the Mediterranean through Düden Waterfall, causing localised fish kills and toxic foaming[17].
- **Toxic Effects of Agricultural Non-Point Source Pollution:** Pesticide use of 14 kg per hectare substantially exceeds global averages[14]. Excessive applications of nitrogen- and phosphorus-based chemical fertilisers exceed the soil's assimilation capacity and are washed into surface waters such as the Aksu, Alara and Düden rivers, causing eutrophication, algal blooms and toxic contamination of bottom sediments[13].
- **Drought-Induced Loss of Dilution Capacity:** Climate change and excessive groundwater abstraction associated with changing cropping patterns, particularly the cultivation of tropical fruits with high water footprints, reduce river flows and eliminate the capacity of receiving waters to dilute discharged pollutants. Insufficiently diluted domestic and agricultural discharges raise heavy metal and pesticide concentrations above lethal thresholds, causing local economic losses in crops irrigated with these waters, including TRY 24.52 per decare for wheat and TRY 88.66 per decare for maize[24].
- **Loss of Blue–Green Infrastructure and Natural Drainage:** As illustrated by Konyaaltı and Kepez, the conversion of floodplains, wetlands and natural drainage channels into concreted development areas has severely impaired the city's natural water purification and flood attenuation functions. Disruption of the natural water cycle accelerates habitat fragmentation[7].

3.7.2.3. Proposed Solutions

Climate-resilient, nature-based and proactive environmental management strategies must be implemented urgently to protect both the quantity and quality of Antalya's water resources. The following engineering and policy measures address the identified problems:

- **Separation of Stormwater and Wastewater Networks:** Stormwater drainage and wastewater sewer networks should be fully separated across the city to prevent intense rainfall from overwhelming sewer systems. Infrastructure capacities should be revised using updated flood discharge estimates for specified return periods, such as 100-year peak flows, that account for climate change[33].
- **Sustainable Urban Drainage Systems (SuDS) and Blue–Green Infrastructure:** Permeable asphalt and concrete, rain gardens, green roofs and bioswales should become mandatory elements of urban design to counteract the effects of impervious surfaces. Culverted or infilled stream channels and degraded wetlands should be restored to support infiltration close to where rainfall occurs[8].
- **Strict Protection Zones in Karst Recharge Areas:** Industrial facilities, uncontrolled waste disposal and intensive fertiliser-based agriculture should be prohibited in karst groundwater recharge catchments, particularly those associated with the Kırkgöz and Kestel swallow holes feeding the Düden River. Sewer networks should be completed urgently in these areas to phase out cesspit use[17].
- **Agricultural Pollution Control at Source and Integrated Pest Management (IPM):** Annual pesticide use, reaching 4,460 tonnes, should be reduced through stringent QR-code tracking and mandatory electronic prescriptions. Farmers should receive training in good agricultural practices,

MRLs, and biological and biotechnical pest control. A deposit-return system should be established for empty agrochemical containers[12].

- **Climate-Adapted Cropping Pattern Planning:** Projections of rising temperatures and declining humidity necessitate catchment-based licensing and restrictions on highly water-intensive tropical fruit production, including bananas and dragon fruit. Cultivation of traditional drought-tolerant species suited to the natural vegetation of the semi-arid Mediterranean, such as olive and carob, should be encouraged instead[20].
- **Revision of Discharge Limits According to Dynamic Dilution Capacity:** Fixed treatment plant discharge limits should be replaced to reflect critically low river flows during summer and autumn. A Total Maximum Daily Load (TMDL) approach linked to prevailing river flow should be applied, with substantially stricter discharge requirements during dry periods, necessitating advanced treatment[24].
- **Wastewater Reclamation and Smart Monitoring:** Treated effluent should undergo advanced filtration to meet irrigation water standards and be reused in agriculture and urban landscaping[37]. The Electronic Ship Monitoring System (EGDS) model should also be adapted to inland waters. Continuous monitoring sensors linked to supervisory control and data acquisition (SCADA) systems should measure total organic carbon (TOC), nitrogen and phosphorus in streams and at discharge points, enabling early detection of pollution pulses that could affect Blue Flag beaches[35].

3.7.2.4. Conclusions

Investigations in the Antalya Basin demonstrate that climate change pressures on water resources extend beyond physical water scarcity and flooding, developing into a complex, multilayered water quality crisis. The comprehensive dataset compiled from reports by the Chamber of Environmental Engineers and Akdeniz University indicates that extreme meteorological events exceed the capacity of the city's existing grey infrastructure and its environmental carrying capacity.

System-level analyses reveal how two contrasting climatic conditions reinforce one another. On the one hand, prolonged severe drought eliminates river dilution capacity, allowing thousands of tonnes of pesticides and heavy metals from agricultural areas to accumulate at lethal concentrations in ecosystems, as illustrated by mass fish kills in the Düden River. On the other hand, rainfall equivalent to several months' totals falling within hours onto dry, impervious surfaces mobilises these highly concentrated contaminants in floodwater and overwhelms infrastructure. The resulting flows enter the Mediterranean together with sewage overflowing from combined sewer systems.

The lack of natural filtration within the karst geology is a particularly hazardous factor accelerating pollutant transfer. These sudden pollution pulses reaching coastal waters threaten the status of 233 Blue Flag beaches through temporary suspensions, directly undermining the tourism economy that provides the city's principal source of income.

These conditions clearly demonstrate that agriculture, tourism, urbanisation and the hydrological cycle cannot be managed independently. Conventional, reactive engineering approaches based on end-of-pipe solutions are no longer adequate. The assumption that "dilution is the solution to pollution" has failed in an era of climate change. Antalya's future depends on constructing separate drainage and sewer systems that treat stormwater as a resource, restoring nature-based blue–green infrastructure, establishing a circular agricultural economy founded on zero-pollution principles, and decisively embedding scientific evidence in decision-making. Protecting freshwater and marine environments is essential to Antalya's long-term liveability and economic stability.

3.7.3. Ecosystem Services and Biodiversity

3.7.3.1. Scope and Current Situation

At the intersection of terrestrial and marine biodiversity, Antalya forms one of the Eastern Mediterranean's most sensitive ecological corridors. However, the accelerating effects of global climate change are placing its critical ecosystem services under severe pressure. Record sea surface temperatures, ocean acidification, seagrass loss, post-fire soil degradation and wetland drying create interconnected, cascading environmental risks.

Climate change has already increased seawater temperatures in the Mediterranean Basin by 1.4°C relative to pre-industrial levels. Underwater measurements in the Gulf of Antalya indicate that sea surface temperatures, previously reaching a maximum of 28°C, have recently risen to record levels of 31–32°C. This extreme warming is accompanied by ocean acidification driven by the absorption of atmospheric carbon dioxide (CO_2) released through fossil fuel combustion.

Carbonic acid formed when CO_2 dissolves in seawater lowers pH and increases acidity, substantially reducing the thickness of calcium carbonate structures produced by calcifying plankton, including coccolith-bearing organisms. Mediterranean warming and acidification have dramatically accelerated the migration of Lessepsian invasive species from the Red Sea through the Suez Canal. More than 1,000 alien species have been identified along Türkiye's coasts, while the number of invasive species reaching the Gulf of Antalya has risen to 67.

Rapidly expanding populations of toxic or venomous predatory species, such as the silver-cheeked toadfish (*Lagocephalus sceleratus*) and common lionfish (*Pterois miles*), are reducing the habitat available to native groupers, severely degrading native biodiversity and undermining local fisheries.

Posidonia oceanica (Neptune grass), a flowering marine plant endemic to the Mediterranean, is regarded as the "lungs" of the sea and a cornerstone of coastal biodiversity. These meadows produce more than 14 litres of oxygen per square metre per day and have a blue carbon storage capacity four to six times greater than terrestrial forests. Capable of storing approximately 2,000 tonnes of carbon per hectare, *Posidonia* meadows are estimated to have absorbed 11–42% of Mediterranean countries' cumulative CO_2 emissions since the Industrial Revolution. Seagrass meadows in Türkiye's seas store approximately 150,000 tonnes of carbon annually, providing a carbon sink service equivalent to that of six million trees. However, these critical habitats are approaching collapse because of extreme seawater warming, uncontrolled yacht anchoring, bottom trawling and coastal land reclamation. In anchoring areas, live *Posidonia* cover declines from 85–90% to 50–60%, while local losses of up to 90% have been reported across the Mediterranean.

In response, the "Project for the Monitoring, Mapping and Sustainable Management of Neptune Grass Meadows along the Lara Coast" was launched in April 2026 through cooperation between the Ecosystem Conservation Association (EKOS) and the Lara Tourism Investors Association (LATUYAB).

The megafires of 2021 caused extensive ecological damage to Antalya's Turkish red pine (*Pinus brutia*) forests, particularly in Manavgat. The fires reduced average carbon storage in the affected region by 10.51%, resulting in substantial carbon emissions. Following the fires, maquis vegetation, including chaste tree, was observed resprouting within as little as one week. Birds, including tits and warblers, used burned branches as perches and contributed to natural restoration through seed dispersal and droppings.

Artificial regeneration and rehabilitation undertaken by the Antalya Regional Directorate of Forestry recorded a 95% seedling survival rate during the first winter, with seedlings reaching an average height of 50–60 centimetres within three years. However, the principal post-fire environmental engineering challenge is severe rainfall-induced erosion on steep, exposed slopes. Vegetation loss undermines carbon regulation,

soil fertility and microbial activity, while soil degradation and the loss of riparian protection zones impair river water quality.

Drying, Eutrophication and Bird Migration Flyways in Freshwater and Wetland Ecosystems

Antalya has a critical wetland network at the intersection of two of the Western Palearctic's four major bird migration flyways. Its wetlands support 235 bird species in Boğazkent, 222 at the Manavgat River mouth, 182 in Denizkent and 179 in Boğaçay. Scientific evidence confirms that migratory birds ringed at the Boğazkent Bird Ringing Station travel as far as Norway, Sweden and Finland. However, these wetlands are under severe pressure from global drought, excessive agricultural water abstraction, illegal rubble dumping and development.

Development and rubble dumping around Yamansaz Wetland have disrupted its hydrological character. Previously drained and subsequently restored sites, such as Lake Avlan, and the Kırkgöz springs feeding the Düden River face eutrophication risks from climate stress and urban waste discharges. Reduced river flows and rising temperatures trigger algal blooms in wetlands, deplete dissolved oxygen and destroy feeding and breeding habitats for waterbirds.

3.7.3.2. Identification of Problems

- **Marine Warming and Invasive Species Dominance:** Sea surface temperatures approaching 32°C in the Gulf of Antalya cause native fish, including annular seabream, striped seabream, saddled seabream and mottled grouper, to move towards cooler waters or disappear locally. The resulting ecological niches are occupied by 67 invasive species, including pufferfish and lionfish.
- **Accelerating Ocean Acidification:** The conversion of absorbed atmospheric CO_2 into carbonic acid lowers seawater pH, impairing shell formation in calcifying organisms at the base of marine food webs and disrupting fish olfaction and orientation.
- **Physical Destruction of *Posidonia* Meadows:** Anchoring by commercial yachts, tourism boats and cruise ships uproots these sensitive meadows, which grow by only 1–6 centimetres annually. Combined with coastal pollution and sediment accumulation, this has caused irreversible losses of up to 90% in local *Posidonia* populations.
- **Loss of Blue Carbon Storage Capacity:** The destruction of *Posidonia* meadows converts major carbon sinks, capable of storing 2,000 tonnes of carbon per hectare, into carbon sources.
- **Post-Fire Erosion and Soil Loss:** The removal of protective vegetation after forest fires increases erosion on sloping karst terrain, causing the loss of fertile, organic-rich topsoil and sedimentation in rivers.
- **Declining Forest Carbon Stocks:** Extensive burning of Turkish red pine forests during the Manavgat fires caused an abrupt 10.51% decline in regional carbon storage capacity, disrupting the greenhouse gas balance.
- **Pressure towards Monoculture Reforestation:** Uniform planting of fire-sensitive Turkish red pine during rehabilitation increases the risk of renewed megafires during future northeasterly windstorms by 60%.
- **Wetland Drying under Development and Waste Pressures:** Opening high-value wetlands such as Yamansaz and Boğazkent to construction through zoning plans, filling them with rubble and draining them through channels increases urban ecosystem vulnerability.
- **Degradation of International Bird Migration Flyways:** The deterioration of wetlands such as Boğazkent, which serve as stepping stones along migration routes extending to Scandinavia,

causes mass mortality among 235 migratory bird species through migratory exhaustion and habitat loss.

3.7.3.3. Proposed Solutions

- **Incentivising the Harvesting and Economic Utilisation of Invasive Species:** Per-fish payments introduced to control pufferfish populations, such as incentives ranging from TRY 10 to TRY 35 depending on the species, should continue with increased funding. Training should support the introduction of palatable, edible species such as lionfish into local gastronomy.
- **Installation of Environmentally Friendly Mooring and Buoy Systems:** Permanent, low-impact mooring buoys and eco-mooring technologies should be installed along the Lara, Konyaaltı and Kaş coastlines where *Posidonia* meadows occur, preventing seabed damage caused by anchoring and anchor dragging.
- **Designation of Sensitive Seagrass Areas:** National legislation should prohibit vessels and yachts exceeding 15 metres in length from anchoring over *Posidonia* meadows. These areas should be designated on digital hydrographic charts as "Sensitive Marine Protected Areas—Anchoring Prohibited".
- **Expansion of the Lara Seagrass Project:** The scientific monitoring, inventory and GIS-based mapping project initiated by EKOS and LATUYAB along the Lara coast should be extended throughout the Gulf of Antalya, supported by AI-enabled monitoring networks.
- **Fire-Resilient Mixed-Forest Restoration:** Rather than monoculture reforestation in burned Turkish red pine areas, restoration should establish green windbreaks of fire-resistant cypress species (*Cupressus*) and ecosystem-based mixed-forest strips capable of reducing the speed of desiccating northeasterly winds and fire intensity by 60%.
- **Erosion Prevention and Riparian Buffer Zones:** Soil conservation and erosion control measures should be completed at microcatchment scale before the first post-fire winter. Natural riparian protection zones at least 35 metres wide, in which tree planting is not permitted, should be retained alongside rivers and streams.
- **Strict Wetland Protection and Restoration:** All construction and rubble dumping should be legally prohibited in the Yamansaz, Boğazkent and Kırkgöz wetlands. Previously drained lakes should have their water-retention functions restored through ecological restoration projects, following the example of Lake Avlan.
- **Limiting Human Disturbance during Bird Migration:** During the peak spring migration period from February to June, strict quotas and stronger enforcement should limit tourism, construction and hunting activities that generate noise disturbance in sensitive areas such as Boğazkent and the Manavgat River mouth.

3.7.3.4. Conclusions

Antalya's terrestrial and marine ecosystems are ecological hotspots where the destructive effects of climate change are being experienced particularly rapidly and severely. The analyses indicate that seawater temperatures reaching 32°C, ocean acidification, losses of up to 90% of *Posidonia* meadows due to anchor damage, post-megafire soil loss and wetland drainage under development pressure are interconnected components of a single systemic breakdown.

The loss of *Posidonia* meadows, the region's underwater forests, severely reduces the city's carbon sequestration capacity and accelerates global warming. Meanwhile, megafires in terrestrial forests intensify

soil erosion and water pollution. Ecological disruption erodes the protective functions of biodiversity, leaving Antalya highly exposed to disease outbreaks, economic damage from invasive species and environmental disasters.

Antalya's sustainable future depends on a fundamental shift towards conservation-led governance that prioritises ecosystem services over profit-driven projects and manages terrestrial, marine and wetland environments as an integrated "ecological security zone".

4. CONCLUSION

Antalya faces an increasingly diverse range of climate risks. Extreme precipitation, heatwaves, drought and sea-level rise are causing growing adverse impacts on infrastructure, agriculture, tourism and ecosystems. Urgent action is required.

Planning processes and infrastructure must be adapted to climate change. Urban plans should integrate disaster and climate data; urban regeneration and building retrofitting should be prioritised according to risk; and blue–green infrastructure should be incorporated into urban systems.

Data sharing and institutional cooperation must be strengthened. Coordination among municipalities, public institutions and the private sector should be improved, supported by smart city solutions, digital infrastructure, climate risk maps and open data platforms.

Ecosystems and water resources must be protected. Post-fire rehabilitation, wetland conservation and sustainable agricultural practices should be implemented alongside measures to address water pollution and invasive species. These actions will strengthen Antalya's natural defences.

Action Steps: Risk maps should be updated regularly, and renewable energy and resilient infrastructure projects should be supported. Participatory approaches should strengthen public education and awareness, while multisectoral disaster–climate coordination structures should be established.

CHAPTER

02

ANTALYA
2050

ANTALYA 2050 / COP31

ENERGY, ENERGY EFFICIENCY, DIGITAL AND GREEN TRANSITION

LOW CARBON · RENEWABLE ENERGY · DIGITALISATION

- Energy efficiency
- Clean energy
- Green transition

A Strategy for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

ENERGY, ENERGY EFFICIENCY, DIGITAL AND GREEN TRANSITION

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Contributing Institutions and Organisations (in Alphabetical Order)

Mediterranean Advertisers Association (ARD)
Antalya Education and Research Foundation (ANTEV)
Antalya Young Businesspeople Association (ANTGİAD)
Antalya Businesswomen Association (ANTİKAD)
Antalya Organised Industrial Zone Technopark Joint-Stock Company
Antalya Teknokent Joint-Stock Company
Antalya Industrialists and Businesspeople Association (ANSİAD)
Western Mediterranean Federation of Industry and Business (BAKSİFED)
Kemer Tourism Professionals and Businesspeople Association (KEMİAD)
Independent Industrialists and Businessmen Association (MÜSİAD), Antalya Branch

Süleyman Demirel University
TMMOB Chamber of Environmental Engineers, Antalya Branch
TMMOB Chamber of Mechanical Engineers, Antalya Branch
TMMOB Chamber of Architects, Antalya Branch
TMMOB Chamber of Agricultural Engineers, Antalya Branch

INTRODUCTION: Antalya's 2050 Vision for Energy, Energy Efficiency, Digital and Green Transition

Antalya is one of the Mediterranean Basin's most important cities, with its natural resources, well-developed tourism infrastructure, agricultural production capacity, young population and substantial renewable energy potential. However, climate change, growing energy demand, pressures on water resources, carbon regulations and global competition are making it necessary for cities to adopt a new approach to development.

Our vision for 2050 is to create a low-carbon and resilient Antalya that jointly advances economic growth, environmental sustainability and social well-being. Within this framework, the aim is to implement a resource-efficient transition across Antalya's energy, transport, industry, agriculture, tourism and building sectors.

In line with this vision, Antalya's priorities are to improve energy efficiency, expand renewable energy use, develop data-driven management models supported by digital technologies, strengthen sustainable transport systems, expand green industrial practices and embed circular economy principles across all sectors. The report examines in detail the policy recommendations, areas of application and transition strategies that will contribute to implementing this vision.

In assessing Antalya's 2050 vision, the energy demand and security of supply requirements arising from population growth must be considered alongside energy efficiency and carbon emission reduction targets.

With a population of approximately 2.8 million, Antalya's total annual energy consumption is estimated at 28.6 TWh including industry and 21.5 TWh excluding industry. Electricity accounts for approximately 12.8 TWh of annual energy consumption. Based on current electricity consumption data, annual per capita electricity consumption is estimated at approximately 4,600 kWh. Tourism activity and seasonal population movements place this figure above the national average.

Buildings account for approximately 40% of final energy consumption in Türkiye, more than 70% of which is used for heating, cooling, ventilation and domestic hot water. In other words, more than one-quarter of the country's total energy consumption is devoted directly to maintaining comfort in occupied spaces. In Antalya, the building sector accounts for approximately half of carbon emissions (47.7%). While industry and transport typically dominate emissions in other Anatolian cities, the high contribution of buildings in Antalya reflects the substantial year-round demand for air conditioning, lighting and water heating in tourism facilities, particularly during summer. Transport follows at 30.2%, reflecting the city's elongated east–west layout and high private vehicle ownership.

Depending on the scenarios applied, Antalya's population is projected to increase by more than 35% by 2050 relative to current levels. Under some high-growth scenarios, it could approach or exceed twice its current size.

Many of the proposed energy efficiency measures involve replacing fossil-fuel-based systems with electric alternatives to reduce carbon emissions. The wider adoption of heat pumps, electric vehicles and electricity-based industrial processes will increase electricity demand despite efficiency gains. At the same time, the greater efficiency of electric systems will help reduce total energy consumption and carbon

emissions. The central objective of future energy systems will therefore be to use energy more efficiently and supply it from low-carbon sources, rather than focusing solely on reducing consumption.

Antalya's population is expected to grow substantially by 2050. Even the most conservative scenarios anticipate growth exceeding 35%. Consequently, total electricity demand would increase by at least the same proportion even if per capita consumption remained unchanged. Electrification in transport, heating and cooling, and industry, expected to accelerate in pursuit of carbon reduction targets, will increase electricity demand further.

Although exponential technological progress has prompted discussion of space-based solar power and other innovative solutions, energy supply security through 2050 should be planned primarily around technologies that are commercially deployable today. Meeting Antalya's future electricity demand will therefore require substantial investment in generation, transmission, distribution and energy storage infrastructure. It is critical that these investments prioritise energy-efficient, low-carbon and sustainable technologies.

The following strategies focus on currently deployable and economically mature technologies to meet the additional electricity demand expected by 2050 sustainably.

1. Distributed Generation and Cogeneration/Trigeneration Systems

Expanding high-efficiency cogeneration and trigeneration in buildings and industrial facilities would substantially improve energy efficiency. These systems meet electricity, heating, cooling and domestic hot water requirements from the same fuel input, significantly increasing overall system efficiency compared with conventional generation methods. Generating electricity close to the point of consumption reduces transmission and distribution losses and strengthens energy supply security.

Cogeneration and trigeneration should be encouraged particularly in tourism facilities, hospitals, shopping centres and large service-sector buildings with high year-round energy demand. Their wider use in industrial facilities requiring process steam and hot water would similarly reduce energy costs and carbon emissions per unit of production. Regulations, incentive mechanisms and financing models should support deployment in suitable sectors.

2. Expanding Solar Energy Systems

Rooftop and ground-mounted solar energy systems should be expanded to maximise Antalya's substantial solar potential. Investment in solar generation for self-consumption should be encouraged in homes, tourism facilities, industrial enterprises, agricultural businesses and public buildings. Regulations and permitting procedures should be simplified, administrative barriers reduced and provisions supporting distributed generation developed. Expanding solar installations integrated with energy storage would also ease grid pressures and improve energy supply security.

3. Assessing Wind Energy Potential

Areas with wind energy potential across Antalya should be identified using up-to-date meteorological data and technical feasibility studies. Identifying economically viable sites would diversify renewable energy supply and strengthen energy security. Planning, permitting and incentive mechanisms should facilitate investment at suitable locations, supported by stronger grid connection infrastructure. Wind should complement solar generation and become an important component of Antalya's low-carbon energy transition.

4. High-Efficiency Combined-Cycle Generation and Waste Heat Recovery Systems

Where additional generation investment is required, high-efficiency integrated systems enabling waste heat recovery should be preferred to electricity-only facilities. If investment in natural-gas-fired combined-cycle plants is considered, their design should support cogeneration or trigeneration rather than electricity generation alone. Recovering waste heat for hot water, steam or cooling production can improve overall system efficiency.

Integration with district heating and cooling would offer particular benefits in organised industrial zones, clusters of tourism facilities and settlements with high energy intensity. This would produce more useful energy from the same fuel input, strengthen supply security and reduce both carbon emissions per unit of useful energy and energy costs.

5. Energy Storage Systems

Energy storage technologies must be expanded to accommodate higher shares of variable renewable generation, including solar and wind. Battery energy storage systems, together with other storage technologies that may become viable in the future, will help balance supply and demand and increase grid flexibility. New renewable energy investments should be encouraged to incorporate storage.

6. Energy Recovery from Wastewater and Waste

Domestic wastewater, organic waste and sewage sludge generated in Antalya contain substantial recoverable energy. Expanding wastewater heat recovery, biogas production and waste-to-energy applications can contribute to energy supply while reducing greenhouse gas emissions. Support should focus particularly on tourism facilities, large residential developments and wastewater treatment plants.

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1. Setting Local Carbon Emission Reduction Targets

Scope and Current Situation

In addressing global climate change, urban areas are both major sources of the problem and central to its solution. Modern urban metabolism requires vast inputs of energy, water and materials while generating waste and emissions. Cities account for approximately 75% of global energy consumption and more than 70% of anthropogenic greenhouse gas emissions.

This structural reality makes carbon management an economic and social imperative alongside its environmental role, particularly in highly climate-vulnerable regions such as the Mediterranean Basin, internationally recognised as a climate hotspot. Well-designed climate action has become a fundamental prerequisite for economic stability, public health and spatial sustainability. In Antalya, the concentration of

tourism, agriculture, services and logistics creates multidimensional exposure to rising regional temperatures, extreme weather, water stress and forest fires.

Antalya's energy demand displays a highly uneven seasonal profile because of increased tourism activity, dramatic temporary population growth and substantial air-conditioning requirements, particularly during summer. Global datasets indicate that cooling can account for up to 50% of electricity demand in hot climates. This uneven demand places substantial pressure on the local grid and increases the city's indirect emissions factor by requiring fossil-fuel-based peaking power plants. Within Türkiye's national 2053 net-zero emissions vision, scientifically grounded, data-driven and measurable city-level carbon reduction policies are essential for major economic centres such as Antalya.

Recent work by Antalya Metropolitan Municipality and district municipalities demonstrates a shift from reactive to proactive climate action. Diplomatic initiatives and infrastructure preparations to host COP31, the 31st Conference of the Parties to the United Nations Framework Convention on Climate Change, in Antalya in 2026 have accelerated the city's integration into global climate action. Antalya has become a testing ground for a climate-resilient city model, carbon budgeting and the localisation of sustainable development objectives, extending its role beyond tourism.

Antalya's SECAP greenhouse gas inventory uses 2019 as its baseline year. Comprehensive calculations establish total provincial greenhouse gas emissions, including industry, at 10,683,551 tonnes of carbon dioxide equivalent (tCO_2e) in 2019. Associated total energy consumption was recorded as 28,623,531 MWh. However, local authorities must define mitigation targets within their direct sphere of influence and jurisdiction.

Since heavy industrial emissions are generally addressed through national environmental policies, central energy authorities and economy-wide instruments such as emissions trading systems (ETS), establishing a separate reference value excluding industry is treated as a methodological standard in urban inventory projections. Excluding industry, Antalya's total urban greenhouse gas emissions in 2019 were calculated at 8,232,919 tCO_2e. With a baseline-year population of 2,511,700, these figures provide a clear basis for calculating per capita emissions.

Antalya's per capita greenhouse gas emissions were 3.28 tCO_2e excluding industry, rising to 4.25 tCO_2e when industry was included. Compared with Türkiye's national average of approximately 6.1 tCO_2e per capita, Antalya's carbon footprint is substantially lower. This primarily reflects the relative absence of carbon-intensive heavy industry and the predominance of services, including tourism, retail and trade, rather than uniformly exceptional environmental performance.

Buildings account for almost half of urban emissions (47.7%). While industry and transport dominate in many Anatolian cities, Antalya's building emissions reflect the enormous year-round demand for air conditioning, lighting and water heating in tourism facilities, particularly during summer. Transport follows at 30.2%, reflecting the city's elongated east–west layout and high private vehicle ownership. This distribution identifies two clear priorities: energy-efficient buildings and public transport decarbonisation. Other sources include energy generation (8.5%), waste and wastewater processes (8.2%), and agriculture and livestock production (6.0%).

As a signatory to the European Covenant of Mayors, Antalya Metropolitan Municipality has incorporated global climate commitments into its institutional and territorial responsibilities. This initiative requires local authorities to make concrete, measurable and time-bound commitments within their jurisdictions. Antalya's principal decarbonisation targets therefore follow two timelines.

For the short and medium term, Antalya Metropolitan Municipality has committed to an absolute 40% reduction in greenhouse gas emissions by the end of 2030 relative to 2019. With a mitigation potential

exceeding 4.5 million tonnes, the building sector is identified as the principal contributor to this target. This underscores the importance of applying stringent energy codes and net-zero energy standards throughout development processes, from building permitting to urban regeneration.

The long-term objective is to reduce carbon emissions to zero by 2050 and achieve carbon neutrality. Moving from a 40% reduction to absolute zero requires a fundamental transformation of urban systems beyond energy efficiency measures alone. Carbon neutrality requires a fully renewable urban energy supply, complete integration of industrial and domestic waste into the circular economy, and compensation for unavoidable residual emissions through nature-based solutions, including afforestation, blue carbon sinks and wetland restoration.

SECAP studies are currently being updated through carbon footprint calculations covering all facilities within Antalya Metropolitan Municipality's boundaries and associated adaptation work. At building scale, a zero-energy building (ZEB) model is being adopted. Passive house design, natural ventilation and insulation are prioritised to reduce the 47.7% contribution of buildings to the city's emissions inventory. Solar thermal water heating systems also offer substantial potential to reduce building emissions.

Identification of Problems

Current local carbon management and mitigation targets face several structural challenges:

- Antalya lacks an up-to-date, integrated carbon inventory.
- Evidence demonstrating the effectiveness of existing initiatives is unavailable.
- Many districts have not yet prepared a SECAP or equivalent assessment.
- Emissions data are insufficiently disaggregated by sector.
- Data sharing between local authorities and the private sector is limited.
- Seasonal tourism-related energy demand is insufficiently integrated into carbon planning.
- Digital carbon monitoring systems are not widely used.
- Mitigation targets lack adequate financial support mechanisms.
- Climate adaptation and emissions mitigation policies are not addressed together.
- Citywide renewable energy use remains below the desired level.

These shortcomings create energy management inefficiencies and impede the measurable implementation of city-level carbon reduction policies.

Proposed Solutions

The following measures are proposed to implement local carbon reduction targets effectively:

- **Citywide Carbon Inventory:** Prepare a sector-based greenhouse gas inventory consistent with Intergovernmental Panel on Climate Change (IPCC) methodologies.
- **Antalya Carbon Budget Model:** Establish a citywide carbon budget covering the 2030 and 2050 targets.
- **Digital Carbon Monitoring Platform:** Develop a data-driven monitoring system integrating municipalities, organised industrial zones and large enterprises.
- **Low-Carbon Tourism Transition:** Develop carbon intensity measurement and certification systems for hotels and tourism facilities.

- **Renewable Energy Integration:** Expand rooftop solar systems and energy storage solutions.
- **Carbon Finance Mechanisms:** Make active use of green bonds, carbon credits and international climate funds.
- **Local Climate Action Plans:** Prepare integrated plans covering energy, transport, waste management, water management and tourism.
- **University–Industry–Government Cooperation:** Collaborate with academic institutions on data analytics and carbon modelling.

Conclusion

Implementing these measures could deliver:

- A 20–30% reduction in citywide energy consumption;
- A substantial decline in tourism-sector carbon intensity;
- Increased renewable energy use;
- Measurable carbon emissions;
- Greater capacity to access international climate funds; and
- Antalya's positioning as a model sustainable city.

A scientifically grounded approach to carbon management would strengthen Antalya's climate resilience and sustainable tourism infrastructure and help establish it as an exemplary city during the COP31 process.

Note: Investment costs for carbon reduction projects vary according to project scale, technology selection, energy prices and financing conditions. Detailed project-specific feasibility studies are therefore required.

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2. Energy Efficiency and Carbon Emission Reduction in Commercial Buildings

Scope and Current Situation

Commercial and industrial buildings account for a substantial share of energy consumption and carbon emissions and therefore play a critical role in addressing climate change. According to the International Energy Agency's 2025 data, buildings account for approximately 30% of global energy demand and have contributed approximately 20% of total demand growth since 2019. Residential buildings account for approximately 70% of building energy demand, with commercial and public buildings accounting for the

remaining 30% [1]. In Türkiye, buildings use approximately 37% of total final energy, while emissions from their operation account for around 30% of total greenhouse gas emissions [2].

Antalya is one of Türkiye's leading tourism centres, receiving more than 17 million visitors annually and accommodating an extensive commercial building stock. According to Ministry of Culture and Tourism data, Antalya has approximately 655,000 tourist beds, the highest accommodation capacity of any tourism destination in Türkiye [3]. In tourism-intensive areas such as Antalya, hotels, shopping centres and large commercial buildings consume substantial energy because of high cooling loads, varying year-round occupancy and continuous operational requirements.

With average annual sunshine exceeding 3,000 hours, Antalya's building cooling demand substantially exceeds heating demand. During the May–October tourism season, energy demand from commercial and accommodation facilities strains grid capacity. Identifying and implementing energy conservation and efficiency measures in energy-intensive accommodation facilities is therefore particularly important [4].

By the end of 2025, Antalya hosted 73 of Türkiye's Green Key-awarded establishments. While encouraging, this figure represents a limited proportion of the city's total accommodation capacity. Much of the existing building stock suffers from inadequate insulation, inefficient mechanical equipment and a lack of energy management systems.

Türkiye's Regulation on Energy Performance in Buildings and Energy Performance Certificate scheme provide an important framework for efficiency. However, a substantial proportion of existing buildings falls short of these standards [5]. Significant changes to building energy requirements were introduced in 2025. The updated TS 825:2024 standard, effective from 1 April 2025, increased the number of climate zones from four to six and incorporated cooling energy calculations for the first time. On the same date, nearly zero-energy building (nZEB) requirements took effect for new buildings of 2,000 m² or more. The BEP-TR calculation methodology was subsequently comprehensively revised on 30 June 2025 [6, 7].

Identification of Problems

The following structural and operational challenges impede energy efficiency improvements in commercial and industrial buildings:

- Insulation and system efficiency are inadequate in many existing buildings.
- Heating, ventilation and air-conditioning (HVAC) systems frequently operate under suboptimal conditions.
- Smart building and automation systems are either absent or used ineffectively.
- A shortage of qualified technical personnel prevents efficient system operation.
- Renewable energy systems are insufficiently deployed.
- Energy monitoring and data management systems are limited.
- Waste heat recovery systems have low adoption rates.
- Passive design principles, including orientation, shading, building form and envelope optimisation, are not systematically integrated into architectural design. Cooling demand is not treated as a central passive design parameter for Antalya's climate.
- Enforcement of the Energy Performance Certificate (EKB) scheme is insufficient, and commercial buildings rated below Class D are not subject to mandatory improvement requirements.

- Access to affordable financing for existing building upgrades, including green loans, energy service company (ESCO) models and grants, is limited. Medium-sized facility owners benefit little from these instruments.
- The global annual building renovation rate is approximately 1%, well below the 2.5% required for net-zero objectives. The rate in Türkiye is even lower [8].

These problems reduce returns on investment, increase energy costs and maintain high carbon emissions.

Proposed Solutions

The following measures are proposed to improve energy efficiency and reduce carbon emissions in commercial and industrial buildings:

- **Expanding Smart Building Systems:** Energy consumption should be monitored and controlled through smart meters and data management systems. Real-time energy management should use programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA) systems, and Internet of Things (IoT) technologies.
- **HVAC Optimisation:** High-efficiency equipment, variable-flow systems and appropriate capacity sizing should reduce energy consumption.
- **Heat Recovery Systems:** Heat recovery equipment should be used more widely in ventilation systems.
- **Heat Pump Applications:** High-efficiency heat pumps should be preferred, particularly for hot water production and space conditioning.
- **Trigeneration Systems:** Large facilities should be encouraged to adopt systems that jointly supply electricity, heating and cooling.
- **Renewable Energy Integration:** Rooftop solar systems should meet part of building energy demand on site.
- **Employment of Qualified Technical Personnel:** More specialist engineers should be employed, supported by continuous training to ensure efficient system operation.
- **Energy Efficiency Upgrades in Existing Buildings:** Comprehensive renovation programmes should combine four components: building envelope upgrades, including external walls, roofs and windows meeting updated TS 825:2024 U-value limits; mechanical upgrades using heat pumps with high seasonal performance or variable refrigerant flow/volume (VRF/VRV) systems; lighting upgrades using LEDs and daylight-responsive controls; and renewable energy integration through rooftop PV and solar water heating. Applying these components together can reduce building energy consumption by 30–60% [1].
- **Thermal Insulation and Passive Building Design:** Under TS 825:2024, Antalya falls within Climate Zone 6, making cooling demand a central passive design parameter. Passive strategies can reduce cooling energy demand by 20–40%. These include south-facing orientation and building form optimisation, solar control through horizontal overhangs and brise-soleil, highly reflective cool roof materials, and layouts supporting cross-ventilation. Buildings complying with the new standard are expected to achieve a 25% reduction in annual energy bills, with nationwide savings of approximately 120,000 tonnes of oil equivalent (toe) and economic benefits of approximately USD 100 million annually [7].

- **Energy Efficiency in Tourism Facilities:** Hotels should expand key-card energy controls, greywater systems and waste heat recovery, while Green Star and sustainable tourism certification should be encouraged. Wastewater-source heat pumps offer particular advantages at hotel scale: while a boiler-based hot water system costs approximately USD 63,000, a heat pump system costs approximately USD 190,000 but can achieve a payback period of 3.5 years. Its CO_2 emissions are also lower by a factor of 1.6–2.2 than those of a natural-gas-fired boiler system [9]. Antalya's large, high-occupancy hotels provide particularly favourable conditions because of their substantial water use and continuous hot water demand.
- **Full Implementation of nZEB Standards in New Buildings:** The nZEB requirement covering new buildings of 2,000 m² or more from 1 January 2025 should be implemented through integrated design from the outset. Energy performance simulations using tools such as EnergyPlus and DesignBuilder should be undertaken during preliminary design, with architects and mechanical and electrical engineers working concurrently. At least 10% of energy used in new buildings must come from renewable sources, and this proportion should be increased. Comparing Energy Performance Certificates with actual consumption data would help close the design–performance gap [6].

Conclusion

Implementing these measures could deliver:

- A 20–40% reduction in energy consumption;
- Substantial carbon emission reductions;
- Operating cost savings; and
- Improved energy supply security.
- For Antalya, this transition would:
- Strengthen tourism-sector sustainability;
- Improve international competitiveness; and
- Support a low-carbon city model.

Costs and other numerical estimates may vary substantially according to facility size, existing infrastructure, equipment brands and energy prices. Detailed feasibility studies should therefore be undertaken for each project.

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3. Energy Efficiency and Carbon Emission Reduction in Agriculture

3.1. General Introduction

Agriculture is strategically important for food production, rural development and economic sustainability. It requires substantial energy inputs, particularly for mechanisation, irrigation, greenhouse climate control, product processing and storage. Improving energy efficiency and reducing carbon emissions in agriculture have become critical to addressing global climate change.

Türkiye is a leading country in protected cultivation and ranked second in Europe after Spain in 2019. Favourable climatic conditions have concentrated protected cultivation along the Mediterranean coast, with approximately 86.5% of total greenhouse area located in the Mediterranean Region. Antalya alone accounts for approximately 40–41% of Türkiye’s protected cultivation area and is the country’s principal greenhouse production centre, with approximately 32,700 hectares of greenhouses [1]. Energy consumption in greenhouse systems is concentrated in heating, cooling, ventilation, lighting and irrigation, making it critical to crop productivity and sustainable growing conditions.

Agricultural energy use in Türkiye is largely fossil-fuel-based. Diesel predominates in agricultural mechanisation, while electricity is used extensively in irrigation and controlled-environment production [2]. Agriculture and livestock production accounted for approximately 4–5% of total final energy consumption in 2023 [3]. Much of this consumption comprises liquid fuels used in tractors and agricultural machinery and electricity used in irrigation and greenhouse operations.

Agriculture has one of Türkiye’s largest machinery fleets. According to the Ministry of Agriculture and Forestry, the country had 1.6 million tractors in 2024, while the total number of road-registered tractors exceeded 2.2 million [4]. This scale indicates substantial carbon reduction potential if electric and hybrid tractor technologies become widely adopted.

Rising energy costs and sustainable production requirements are also increasing the importance of renewable energy sources, including biomass, solar and geothermal energy, in agriculture [5]. Türkiye has made substantial progress in renewable energy investment in recent years. By early 2026, installed solar capacity had reached 25,827 MW [6], while renewables accounted for more than 62% of total installed electricity generation capacity [7]. These developments offer significant opportunities to expand renewable energy use in agricultural irrigation, farm businesses and greenhouse facilities.

According to the 2024 National Greenhouse Gas Inventory data published by TÜİK, Türkiye's total greenhouse gas emissions amounted to 584.5 million tonnes of CO_2 equivalent. Agriculture accounted for approximately 12.6%, or around 73.5 million tonnes of CO_2 equivalent [8]. These figures underline the importance of expanding energy efficiency measures and low-carbon technologies in agriculture to address climate change.

3.2. Energy Efficiency and Carbon Emission Reduction in Greenhouses

Scope and Current Situation

Greenhouse production is a key component of modern agriculture because it enables controlled agricultural production throughout the year. However, greenhouse heating, cooling, ventilation, irrigation, fertilisation and lighting systems consume substantial amounts of energy. Antalya, where protected cultivation is particularly intensive, has one of Türkiye's largest greenhouse areas, and greenhouse operations account for a significant share of regional energy consumption.

Nevertheless, energy management remains insufficiently effective in many greenhouse businesses. Fossil-fuel-based heating systems, particularly those used during winter, result in high energy costs and carbon emissions. During summer, ventilation and cooling systems consume substantial amounts of electricity.

Data from the International Energy Agency (IEA) and the Food and Agriculture Organization (FAO) indicate that improving agricultural energy efficiency reduces both production costs and greenhouse gas emissions substantially. In regions with intensive greenhouse production, such as Antalya, energy efficiency measures offer an important opportunity to address climate change.

Identification of Problems

The principal barriers to energy efficiency in greenhouse operations are summarised below:

- Single-layer plastic coverings cause substantial energy losses in many greenhouses.
- Fossil-fuel-fired boilers are widely used, resulting in high carbon emissions.
- Heating system automation and temperature control are inadequate.
- Ventilation systems are frequently operated without sufficient consideration of energy efficiency.
- Renewable energy adoption is limited.
- Most businesses do not regularly monitor and analyse energy consumption.
- A shortage of technical personnel limits effective energy management.
- Modern climate control systems and sensor technologies are insufficiently deployed.
- Carbon footprint measurement remains very limited.

These problems increase production costs and maintain high greenhouse gas emissions.

Proposed Solutions

The following measures should be expanded to improve energy efficiency and reduce carbon emissions in greenhouse operations:

- **High-Performance Greenhouse Covering Systems:** Double-layer coverings, thermal screens and energy-efficient cladding materials should be used to reduce heat losses.

- **Smart Climate Control Systems:** Automation systems that continuously monitor temperature, humidity, CO_2 and light levels should be expanded. Sensor-based management can prevent unnecessary energy consumption.
- **Thermal Energy Storage and Heat Recovery:** Heat stored during the day should be used at night, and energy discharged through ventilation systems should be recovered.
- **Heat Pump Technologies:** High-efficiency heat pumps should reduce fossil fuel use in greenhouse heating.
- **Geothermal Energy Applications:** Renewable energy use for greenhouse heating should be encouraged in areas close to geothermal resources.
- **Solar Energy Systems:** Solar installations in suitable locations should meet part of electricity demand on site.
- **Energy-Efficient Fans and Pumps:** Fans and pumps equipped with variable-speed drives should reduce electricity consumption.
- **Energy Monitoring and Management Systems:** Digital platforms enabling real-time energy consumption monitoring should be expanded.
- **Carbon Footprint Monitoring:** Regular calculation and reporting of greenhouse operational carbon emissions should be encouraged.
- **Technical Training and Capacity Building:** Greenhouse managers and technical personnel should receive energy management training.

Conclusion

Energy efficiency investments in greenhouse operations can:

- Reduce energy consumption by 20–50%;
- Substantially reduce heating-related carbon emissions;
- Lower production costs;
- Increase resilience to energy price fluctuations; and
- Strengthen the sustainability of agricultural production.

In Antalya, greenhouse energy efficiency investments would contribute to regional development and Türkiye's net-zero emissions targets. Solar-supported greenhouse systems, smart climate control and high-efficiency heating technologies offer particularly important opportunities.

For example, investment in thermal screens and automation for a modern five-hectare greenhouse may range from approximately USD 80,000 to USD 250,000, depending on project specifications. Payback periods generally range from three to seven years, depending on energy prices, greenhouse size and climatic conditions. However, costs and payback periods can vary substantially according to project-specific technical and economic conditions. Detailed feasibility studies are therefore required before final investment decisions.

3.3. Renewable Energy Use in Agricultural Production

Scope and Current Situation

Energy is an important input across agricultural activities, including irrigation, product processing, cold storage, greenhouse operations, livestock facilities and agricultural machinery. Rising energy costs and efforts to address climate change are increasing the importance of renewable energy in agriculture.

Türkiye has substantial solar energy potential. Its average annual sunshine duration is approximately 2,741 hours, and average annual solar irradiation is approximately 1,527 kWh/m². With annual sunshine approaching 3,000 hours, Antalya is among the country's most favourable regions for solar energy.

Agriculture offers significant opportunities for renewable energy deployment. Solar systems, biogas plants, biomass energy production and energy recovery from agricultural waste can reduce energy costs and carbon emissions.

Nevertheless, many agricultural businesses in Türkiye still meet their energy needs through grid electricity and fossil fuels. Irrigation systems, cold stores and agricultural processing facilities incur substantial operating costs because of their high energy consumption.

In Antalya, intensive agricultural production, a well-developed greenhouse sector, extensive protected cultivation, fruit and vegetable processing facilities and substantial solar potential provide important advantages for renewable energy investment.

Identification of Problems

The principal barriers to renewable energy adoption in agricultural production are summarised below:

- Despite high energy costs, renewable energy investment remains insufficient. Initial investment costs impose a significant financing burden on many producers.
- Small and medium-sized businesses lack sufficient technical knowledge and project development capacity.
- Energy production from agricultural waste remains limited.
- The number of biogas and biomass facilities is low relative to the available potential.
- Financial and technical barriers constrain rooftop and ground-mounted solar deployment.
- Energy storage costs remain high.
- Technical advisory services for renewable energy investment are insufficiently available.
- Carbon footprint calculation and reporting remain limited among agricultural businesses.

These conditions maintain high agricultural energy costs and prevent the sector's full carbon reduction potential from being realised.

Proposed Solutions

The following measures should be supported to expand renewable energy use in agricultural production:

- **Expanding Agricultural Solar Energy Systems:** Rooftop or ground-mounted solar systems should be installed to serve irrigation systems, cold stores and agricultural processing facilities.
- **Promoting Agrivoltaics:** Agrivoltaic systems, which combine agricultural production and electricity generation on the same land, should be supported following an integrated assessment of their advantages and disadvantages. Before implementation, detailed analysis should assess the additional investment costs of elevated panels, potential yield losses in crops requiring full

sunlight, restrictions on agricultural machinery movement, and the effects of panel row spacing and shading design on agricultural production.

Potential long-term yield losses resulting from poorly planned panel layouts and shading should be considered alongside effects on soil and ecosystem health, human well-being and comfort, including glare and local temperature increases. Projects should be designed to suit cropping patterns and regional climatic conditions. Conversely, appropriate crop selection and system design can help retain soil moisture, reduce irrigation requirements and offer important climate adaptation benefits in some regions.

Grazing land offers particular agrivoltaic potential because it can accommodate renewable electricity generation while allowing livestock grazing to continue.

- **Solar-Powered Irrigation Pumps:** Solar-powered systems should increasingly replace conventional electric or diesel irrigation pumping arrangements.
- **Biogas Production from Agricultural Waste:** Animal manure, crop residues and organic waste should be processed in biogas plants for energy production.
- **Biomass Energy Systems:** Investment in energy recovery from pruning residues, greenhouse plant waste and other agricultural residues should be encouraged.
- **Support for Energy Storage:** Batteries and other storage solutions should improve the effective use of renewable energy.
- **Carbon Credits and Green Finance:** Agricultural businesses investing in renewable energy should have improved access to carbon markets.
- **Cooperative-Based Energy Generation:** Joint renewable energy investment through producer associations and cooperatives should be encouraged.
- **Technical Training and Advisory Services:** Producers' knowledge and project development capacity for renewable energy investment should be strengthened.

Conclusion

Expanding renewable energy use in agricultural production can:

- Reduce energy costs by 30–70%;
- Substantially reduce fossil fuel consumption;
- Lower the carbon footprint of agricultural production;
- Increase producers' resilience to energy price fluctuations;
- Strengthen rural energy supply security; and
- Contribute to Türkiye's net-zero emissions targets.

Antalya's substantial solar potential and intensive agricultural activity create significant investment opportunities. Solar-powered irrigation, rooftop solar installations on agricultural buildings and energy recovery from agricultural waste would contribute substantially to sustainable regional development.

For example, a solar power plant serving agricultural operations with approximately 1 MW of installed capacity may cost between USD 600,000 and USD 900,000, depending on technology, equipment selection, site conditions and market circumstances. Biogas investment costs also vary significantly with

facility capacity. Detailed technical, economic and environmental feasibility studies are therefore required before investment decisions.

3.4. Electrification of Agricultural Machinery and Low-Carbon Mechanisation

Scope and Current Situation

Agricultural mechanisation is essential for increasing productivity and reducing labour requirements. However, most agricultural machinery currently operates on diesel, generating substantial greenhouse gas emissions. Tractors, combine harvesters, other harvesting machines, loaders and agricultural equipment are important sources of direct agricultural carbon emissions.

The electrification transition that began in transport as part of global climate action is also accelerating in agricultural machinery. Electric tractors, hybrid machinery and autonomous agricultural vehicles are being developed and introduced in many countries, particularly across the European Union.

In Türkiye, agricultural mechanisation remains predominantly diesel-based. Much of the tractor fleet is ageing and less energy-efficient than newer technologies. Smart and precision agriculture adoption also remains below the desired level.

In Antalya, intensive fruit, vegetable and protected crop production keeps agricultural machinery in use throughout the year, increasing fuel consumption and associated carbon emissions. Electrification and low-carbon mechanisation therefore represent important opportunities to support regional sustainability objectives.

Identification of Problems

The principal barriers to energy efficiency and carbon reduction in agricultural machinery are:

- Most machinery is fossil-fuel-powered.
- Much of the tractor fleet consists of older technologies approaching the end of their economic life.
- Fuel consumption and maintenance costs impose a significant financial burden on producers.
- Electric and hybrid machinery adoption is very limited.
- Charging infrastructure and supporting energy systems are insufficiently developed.
- Precision agriculture and digital technology adoption are limited.
- Agricultural carbon emissions are not widely measured or reported.
- Technical servicing and maintenance infrastructure for electric equipment are inadequate.
- Producers may face limited access to new technologies and financing.

These conditions maintain high production costs and hinder agricultural greenhouse gas reductions.

Proposed Solutions

The following measures are proposed to expand electrification and low-carbon mechanisation:

- **Expanding Electric Tractors:** Electric tractors suitable particularly for small and medium-sized farms should be encouraged. They can reduce operating costs and substantially lower carbon emissions.
- **Supporting Hybrid Machinery:** Hybrid agricultural machinery should be encouraged where fully electric solutions are not yet widely available.

- **Expanding Precision Agriculture:** GPS guidance, automatic steering, sensors and variable-rate application systems should reduce fuel consumption.
- **Autonomous Agricultural Vehicles and Robotics:** Next-generation autonomous machinery should improve operational scheduling and reduce unnecessary energy use.
- **Farm Charging Infrastructure:** Rural charging infrastructure should support electric agricultural machinery.
- **Renewable-Energy-Integrated Mechanisation:** On-farm solar systems should be encouraged to supply electric machinery.
- **Smart Fleet Management:** Digital systems should monitor machinery operating hours, fuel consumption and maintenance requirements.
- **Low-Carbon Fuel Alternatives:** Biodiesel, biomethane and other low-carbon fuels should be assessed where electrification is not feasible in the short term.
- **Machinery Replacement and Modernisation:** Incentives should support the replacement of older, inefficient machinery.
- **Technical Training and Capacity Building:** Awareness and training on next-generation mechanisation technologies should be expanded.

Conclusion

Expanding electrification and low-carbon mechanisation can:

- Reduce fuel consumption by 20–60%;
- Substantially lower agricultural carbon emissions;
- Reduce operating and maintenance costs;
- Optimise input use through precision agriculture;
- Increase productivity and competitiveness; and
- Strengthen agricultural climate adaptation capacity.

In Antalya, expanding electric and smart machinery in fruit, vegetable and protected crop production would deliver significant environmental and economic benefits. Integrating agricultural production with renewable energy systems could contribute substantially to regional carbon reduction targets.

For example, some commercially available compact electric tractors have higher purchase costs than equivalent diesel models, but lower fuel and maintenance expenditure can produce payback periods of five to ten years, depending on farm scale. Investment costs vary significantly with machinery power, battery capacity, utilisation intensity, energy prices and technological developments. Each investment therefore requires a separate technical and economic assessment.

3.5. Energy Efficiency and Carbon Emission Reduction in Irrigation Systems

Scope and Current Situation

Water is a fundamental input to agricultural productivity, and irrigation is critical to sustainable production in many regions. However, irrigation pumps, pressurisation equipment and water distribution infrastructure consume substantial energy. Improving irrigation energy efficiency is therefore essential to reducing both agricultural production costs and greenhouse gas emissions.

Türkiye faces increasing drought risk and pressure on water resources because of climate change. Agriculture accounts for approximately 75% of national water consumption. Improving both water and energy efficiency in irrigation has therefore become a strategic necessity.

Antalya has high irrigation requirements because of its extensive protected cultivation, fruit production and high-value agriculture. Pumping energy creates substantial operating costs, particularly in groundwater-based irrigation. Rising temperatures and irregular precipitation associated with climate change further increase irrigation requirements.

Many businesses continue to use inefficient pumps, unsuitable pipe systems and conventional irrigation methods, resulting in unnecessary energy consumption and inefficient water use.

Identification of Problems

The principal barriers to irrigation energy efficiency are:

- Inefficient pumping systems are widely used.
- Ageing or unsuitable pipes cause pressure losses.
- Uncontrolled flooding and conventional surface irrigation remain in use in some areas.
- Automation and remote monitoring are insufficiently deployed.
- Irrigation scheduling frequently fails to reflect actual water requirements.
- Groundwater-based irrigation entails high energy consumption.
- Solar-powered irrigation remains limited.
- Maintenance and performance checks are not conducted regularly.
- Producers may lack sufficient technical knowledge of energy and water efficiency.
- Integrated monitoring of energy and water consumption is uncommon.

These conditions increase production costs and constrain efficient water and energy use.

Proposed Solutions

The following measures should be expanded to improve irrigation energy efficiency and reduce carbon emissions:

- **Pressurised Irrigation:** Modern systems, including drip and sprinkler irrigation, should be supported to improve water and energy use efficiency.
- **High-Efficiency Pumps:** Pumps with high energy efficiency ratings should reduce electricity consumption.
- **Variable-Frequency Drives (VFDs):** Variable-speed control of pump motors should optimise energy use according to demand.
- **Solar-Powered Irrigation:** Solar systems should supply irrigation pumps to reduce operating costs and carbon emissions.
- **Smart Irrigation Automation:** Soil moisture sensors, meteorological data and remote control should ensure irrigation matches actual requirements.
- **Infrastructure Modernisation:** Pipes and water conveyance lines should be renewed to reduce pressure losses.

- **Energy and Water Monitoring:** Digital platforms should jointly monitor irrigation energy consumption and water use.
- **Improved Groundwater Management:** Planning and management measures should reduce energy consumption in deep-well irrigation.
- **Precision Agriculture Integration:** Satellite imagery, sensors and data analytics should optimise irrigation decisions.
- **Training and Technical Advice:** Producers should receive training and advisory support on energy-efficient irrigation.

Conclusion

Expanding energy efficiency measures in irrigation can:

- Reduce irrigation-related energy consumption by 20–50%;
- Substantially improve water use efficiency;
- Lower agricultural production costs;
- Reduce pressure on groundwater;
- Substantially reduce carbon emissions; and
- Increase climate adaptation capacity.

In Antalya, combining substantial solar potential with modern irrigation technologies offers significant opportunities. Solar-powered irrigation, smart automation and high-efficiency pumps can reduce energy costs and support more sustainable water management.

Investment costs for solar-powered irrigation pumps vary considerably according to pump capacity, well depth, irrigated area and installed solar capacity. Nevertheless, energy cost reductions can produce payback periods of three to seven years in many applications. Since costs and economic performance depend on project conditions, detailed technical and financial feasibility studies are required for each investment.

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4. Energy Efficiency and Carbon Emission Reduction in Industry

4.1. Industrial Energy Efficiency, Carbon Emission Reduction, Industrial Symbiosis and the Transition to Green Organised Industrial Zones

Scope and Current Situation

Industry accounts for a substantial share of Türkiye's total energy consumption and greenhouse gas emissions. Regulations such as the European Green Deal and Carbon Border Adjustment Mechanism (CBAM) make the rapid implementation of energy efficiency, carbon management and sustainable production practices increasingly necessary.

Green Organised Industrial Zones (Green OIZs) represent a new generation of industrial areas founded on low-carbon production, renewable energy, energy and water efficiency, circular economy principles and industrial symbiosis.

Antalya Organised Industrial Zone has introduced several pioneering Green OIZ initiatives. These include certification or verification covering:

- TS EN ISO 50001 Energy Management Systems;
- TS EN ISO 14001 Environmental Management Systems;
- TS ISO 46001 Water Efficiency Management Systems; and
- Greenhouse Gas Emissions Report Verification.

Following assessments against Turkish Standards Institution (TSE) criteria, Antalya OIZ has also attained Silver-Level Green OIZ status.

Cleaner production assessments indicate that energy efficiency improvements in just 13 companies could prevent approximately 1,450 tonnes of CO_2-equivalent emissions annually and generate approximately TRY 12 million in annual savings.

In addition:

- A total of 114 unlicensed solar power plants are operational.
- Total installed capacity has reached 93 MW.
- Waste sludge is utilised as an alternative fuel through the Solar Sludge Drying Facility.
- SCADA-based digital energy and resource management systems are used.
- Inter-company resource efficiency and circular economy practices have been developed through industrial symbiosis initiatives.
- Composting organic waste supports carbon footprint reduction and resource recovery.

According to United Nations Industrial Development Organization (UNIDO) studies, industrial symbiosis can improve energy use efficiency by 10–20%.

Identification of Problems

Energy Efficiency and Carbon Management

- Industrial energy efficiency potential is not fully realised.
- Old, inefficient equipment causes energy losses.
- Waste heat recovery remains insufficiently deployed.
- Regular carbon emissions measurement and reporting are not undertaken by all businesses.
- Electrification and the transition away from fossil fuels are progressing slowly.

Green OIZ Transition

- Integrated, zone-wide energy management remains insufficient.

- Renewable energy use has not reached the desired level.
- Shared energy infrastructure and energy-sharing models are underdeveloped.
- Water reclamation and reuse systems are limited.
- Digital energy management is not widely adopted across all businesses.

Industrial Symbiosis and the Circular Economy

- Inter-company data sharing is inadequate.
- Waste and by-product inventories are neither sufficiently current nor accessible.
- Digital resource-sharing platforms are absent.
- Technical knowledge and awareness of circular economy practices are insufficient.
- Regulatory procedures hinder some symbiotic applications.

Finance and Competitiveness

- Initial investment costs for energy efficiency measures are high.
- Companies may struggle to access incentives, grants and financing.
- Technical capacity concerning CBAM and carbon regulations varies.
- Carbon reporting and sustainability certification create additional costs, particularly for SMEs.

Proposed Solutions

Energy Efficiency and Carbon Emission Reduction

- Conduct regular energy audits across all businesses.
- Replace inefficient motors and equipment with high-efficiency technologies.
- Expand waste heat recovery.
- Support electrification and reduce fossil fuel dependence.
- Expand carbon footprint calculation and reporting systems.

Expanding the Green OIZ Model

- Establish carbon-neutral OIZ targets.
- Install shared rooftop and ground-mounted solar systems.
- Develop energy storage and smart grid applications.
- Expand SCADA and digital energy management.
- Support rainwater harvesting, greywater use and wastewater reclamation.
- Establish centralised recycling and biological waste recovery facilities.

Industrial Symbiosis and the Circular Economy

- Establish an Industrial Symbiosis Database within the OIZ.
- Develop digital platforms for sharing waste, energy and water data.
- Utilise waste heat in industry, greenhouses and district energy systems.
- Establish sectoral clusters based on resource sharing.

- Support research, development and pilot applications through university–industry cooperation.
- Expand circular economy training and capacity building.

European Green Deal and CBAM Alignment

- Establish shared carbon data management systems in OIZs.
- Develop centralised carbon monitoring and reporting infrastructure.
- Establish joint training and advisory centres for businesses.
- Strengthen incentives and financing for green transition investment.
- Facilitate access to green finance for carbon reduction projects.

Conclusion

Energy efficiency, carbon reduction, industrial symbiosis and Green OIZ practices are critical instruments for the sustainable transformation of Antalya's industry. Their expansion can deliver:

- Lower energy consumption and costs;
- Substantial carbon emission reductions;
- Increased renewable energy use;
- Improved water and raw material efficiency;
- Reduced waste generation;
- Wider adoption of circular economy practices;
- Greater international competitiveness; and
- Easier alignment with the European Green Deal and CBAM.

Practices implemented in Antalya Organised Industrial Zone provide a successful, scalable model for low-carbon industrial transformation in Türkiye.

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4.2. Energy Transition in Organised Industrial Zones

Scope and Current Situation

Organised Industrial Zones offer substantial spatial potential for renewable energy integration through extensive roof areas, unused land around industrial facilities and shared recreational areas. On-site

generation and self-consumption, whereby facilities generate energy where it is used, minimise transmission and distribution losses and ease peak demand on the national grid. However, some roofs are unsuitable, and businesses with existing solar installations may require additional capacity.

Renewable energy integration in OIZs should extend beyond conventional factory roofs. To maximise land-use efficiency, factory and OIZ parking areas should be equipped with solar carports, floating solar systems should be installed over wastewater treatment basins to reduce evaporation, and building-integrated photovoltaic design should become mandatory in new facilities.

On-site generation stabilises industrial energy procurement costs and protects businesses against price fluctuations during global energy crises. By reducing unit production costs, particularly in energy-intensive sectors, it improves export competitiveness. Renewable generation also directly reduces the carbon footprint of finished products under CBAM criteria. Products manufactured using clean energy create new opportunities for Antalya's industrial exporters in international markets.

In Antalya, where tourism-related air-conditioning demand places substantial pressure on the grid during summer, OIZs becoming self-generating "energy islands" is particularly important. Co-locating generation and consumption helps prevent substation overheating and provides a strategic buffer for citywide energy security and supply continuity.

Not every industrial facility has a suitable roof structure, sufficient structural capacity, favourable orientation or the financial resources to install its own solar system. Shared solar power plants and energy cooperatives offer an innovative response. Led by the OIZ legal entity or consortia of local industrial businesses, shared plants should be developed on unallocated OIZ land, marginal land or large integrated canopy systems.

Shared solar generation can extend access to renewable energy beyond large companies and create more equitable opportunities for SMEs. Businesses unable to invest in roofs because they are tenants, or whose buildings are unsuitable because of production processes, such as factories using heavy vibrating machinery or marble processing facilities, can participate as green investors. This would help businesses of all sizes address CBAM obligations.

A single large shared plant can substantially reduce unit costs compared with 30 separate small installations on 30 factory roofs. Bulk procurement of panels, inverters and transformers lowers capital expenditure (CAPEX), while centralised security, cleaning, insurance and maintenance improve operating expenditure (OPEX) efficiency. Large, multistakeholder cooperative projects also present a more attractive and credible profile for international green climate funds and low-interest financing.

Electricity from shared plants need not be delivered directly to individual factories through dedicated cables. Through virtual net metering, electricity supplied to the grid can be automatically credited against cooperative members' metered consumption in proportion to their shares. In line with the COP31 vision, digital smart contracts and blockchain-based allocation could improve transparency, security and confidence in energy sharing.

Microgrids provide the hardware and software foundation for twenty-first-century energy transition in OIZs. A microgrid is a local energy network that integrates distributed resources, including rooftop solar, wind and biomass, with storage and smart consumption points within a defined geographical area. It can operate alongside the main grid or independently, optimising real-time generation and consumption and reducing losses.

Energy Supply Security and Islanded Operation

Given Antalya's vulnerabilities to extreme heatwaves, forest fires and grid overloads associated with seasonal population growth, microgrids offer important protection for industry. During grid faults, voltage fluctuations or outages, a microgrid can isolate itself within seconds and enter islanded operation. This autonomous capability maintains operations in cold stores, precision CNC machinery, continuous casting furnaces and automated lines, preventing product and raw material losses worth millions of lira.

Artificial Intelligence and Smart Load Management

Microgrids combine physical networks with IoT technologies and advanced analytics. Smart meters and AI algorithms processing meteorological information, such as forecast cloud cover and wind strength, can predict the following day's supply–demand balance. During expensive peak periods, systems can automatically reduce facility demand through demand response and deploy stored renewable energy to minimise costs.

Blockchain and smart contracts can establish transparent, real-time, peer-to-peer energy trading between OIZ facilities. This enables energy symbiosis as an advanced form of industrial ecology.

The variability of solar and wind is a major technical challenge for industry requiring stable, continuous power. Energy storage is central to addressing this problem. Industrial-scale lithium-ion batteries, flow batteries and thermal storage can retain daytime solar surpluses for night-shift use and improve power quality across the OIZ.

Peak Shaving and Energy Arbitrage

Storage can function as an active financial management tool as well as backup power. Peak shaving reduces electricity bills by using stored energy when grid electricity is most expensive. Energy arbitrage, which involves charging batteries during low-price periods and discharging them during high-price periods, provides additional cost optimisation flexibility.

Storage also improves power quality and protects sensitive production. By limiting brief voltage fluctuations and frequency deviations, it supports continuity and helps prevent damage to CNC machines, robotic systems and sensitive electronics. Industrial batteries can provide ancillary services, including frequency regulation and reactive power compensation, to maintain stable electricity supply.

While lithium-ion technologies are important for short-duration balancing, fully renewable heavy industry requires longer-duration storage. Vanadium redox flow batteries (VRFBs) and thermal batteries storing industrial waste heat in specialised alloys can help close this gap and support OIZ net-zero and carbon-neutrality objectives.

Under the EU CBAM, integrated OIZ-level carbon reduction plans have become essential for exporters seeking to avoid substantial border carbon costs. These should be practical, financially valuable projects incorporating digital inventories, clear sectoral reduction pathways and physically integrated circular economy practices.

Data-Driven Digital Carbon Accounting

Managing an OIZ's carbon footprint requires timely measurement. Instead of relying exclusively on annual manual reporting, IoT sensors and cloud-based software should support an OIZ digital twin. This would enable real-time monitoring, verification and transparent reporting of Scope 1 emissions from direct fuel use, Scope 2 emissions from purchased electricity, and Scope 3 emissions from supply chains, logistics and waste, in line with ISO 14064 standards, supporting recognition as a green supplier.

Identification of Problems

1. Insufficient grid connection capacity, even for solar installations intended only to meet businesses' own demand, is among industry's most significant current barriers.
2. Renewable generation, industrial lithium-ion storage and smart metering networks require high, often foreign-currency-linked initial investment. This creates a substantial barrier for SMEs with limited capital and immediate cash-flow pressures. Conventional banks' risk perceptions and the limited availability of long-term, low-interest, project-based green loans further constrain investment.
3. Existing distribution networks were designed primarily for one-way flows from central generators to consumers. Modern infrastructure capable of managing voltage fluctuations and two-way flows from extensive rooftop solar and storage is lacking. Substations, sensors and SCADA systems often lack the smart grid capabilities required for this complexity, creating technical bottlenecks.
4. Energy technology is advancing faster than regulation. Shared solar projects, energy cooperatives and microgrid-based peer-to-peer trading remain in regulatory grey areas. Restrictive rules and slow procedures concerning ownership transfers, taxation of network charges and virtual financial settlement between businesses hinder implementation.
5. Businesses differ substantially in their understanding of carbon footprint calculations, Scope 1, 2 and 3 management and international verification requirements. Compliance may be treated as paperwork rather than strategic transformation. A shortage of green-skilled professionals, including energy systems engineers and sustainability specialists, is a critical operational weakness.

Proposed Solutions

The energy transition in Antalya's OIZs is a major economic development initiative supporting exports, employment and global competitiveness. A transition supported by Industry 4.0 technologies, circular economy networks and digital green certification could position Antalya as a regional centre for technology and climate innovation.

During COP31 preparations, shared renewable generation, microgrids, large-scale storage and clear, measurable OIZ-level carbon reduction plans would position Antalya as a low-carbon industrial centre in the Eastern Mediterranean. Sound planning, a robust legal framework and sustainable green finance would make this transition a powerful instrument for achieving Antalya's 2053 net-zero vision. This is particularly relevant to an industrial economy oriented towards high-value production and closely linked to tourism, logistics and modern agriculture.

Conclusion

Four illustrative applications are presented below. The figures depend on project scale, technology, energy prices and financing conditions. Detailed project-specific feasibility studies remain necessary.

1. Integrating a 2 MW floating solar installation into Antalya OIZ's wastewater treatment facility or irrigation reservoirs could increase panel generation efficiency by 10–15% through the cooling effect of the water surface and prevent millions of litres of summer evaporation. Direct, zero-emission generation could meet the treatment plant's continuous energy requirements and potentially eliminate wastewater operating costs.
2. Thirty SMEs with unsuitable roofs or tenant status could establish a Green Energy Cooperative with the OIZ Regional Directorate acting as guarantor. A digitally managed 10 MW shared plant

could be installed on 100 decares of unused rocky land within the OIZ. Monthly generation would be credited against members' bills according to their purchased shares, scaled to business size. Renewable Energy Guarantees of Origin (YEK-G) certificates obtained through the cooperative would enable participating SMEs to demonstrate a zero product carbon footprint for exports to Europe and gain a competitive advantage.

3. A packaging facility closed on weekends could sell surplus rooftop solar generation directly to a neighbouring plastics injection-moulding factory operating continuously, using microgrid software and peer-to-peer trading. The plastics factory would obtain local, zero-carbon electricity below grid prices, while the packaging business would earn additional revenue from otherwise unused rooftop capacity.
4. A 10 MWh industrial lithium-ion battery installation at the OIZ's main substation, integrated with AI-enabled smart grid software, could charge during periods of abundant, inexpensive daytime solar generation and supply industrial facilities between 18:00 and 22:00. These hours coincide with expensive electricity and intense tourism-related air-conditioning pressure on the national grid. The system could generate substantial savings and significantly reduce citywide risks of substation failure and voltage drops.

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4.3. Integrating SMEs into the Green Transition

Scope and Current Situation

Antalya’s economy consists predominantly of small and medium-sized enterprises (SMEs). Operating in tourism, agriculture, food processing, logistics, services and small-scale manufacturing, SMEs underpin provincial employment, production and exports.

The accelerating global green transition, together with the European Green Deal and CBAM, creates new business obligations. Measuring carbon footprints, improving energy efficiency, reducing resource use and adopting sustainable production are increasingly necessary for competitiveness and export capacity.

Given Antalya’s economic structure, priority sectors include tourism facilities, protected cultivation businesses, food processing, cold-chain and logistics operators, and small and medium-sized manufacturers. Rising energy costs, international regulation of carbon-intensive products and sustainability requirements in supply chains are accelerating this transition.

Many SMEs in Türkiye and Antalya lack sufficient technical capacity in energy management, carbon reporting, green finance and sustainable production. Successful transition therefore requires coordinated technical support, financing, training and guidance.

Identification of Problems

- Energy management systems and efficiency measures are insufficiently adopted.
- Digital infrastructure for regular energy monitoring and analysis is limited.
- Carbon footprint calculation and reporting capacity are low.
- Awareness of the European Green Deal and CBAM is insufficient.
- Many businesses lack the data collection systems needed to measure emissions.
- Many SMEs struggle to access green finance and incentives.
- Initial costs of efficiency and renewable energy investment are perceived as high.
- Access to specialist advice and technical support is limited.
- Knowledge of circular economy, resource efficiency and sustainable production is insufficient.
- Sector-specific carbon management guidance is inadequate.
- Carbon management in tourism, agriculture and services lags behind industry.
- Many SMEs lack organisational structures for sustainability and carbon management.

Proposed Solutions

Energy Efficiency Programmes for SMEs

- Expand SME energy efficiency support programmes.
- Conduct regular energy audits and performance assessments.
- Encourage LED upgrades, efficient motors, automation and variable-speed drives.
- Support HVAC, hot water and lighting efficiency projects in tourism facilities.
- Modernise irrigation, pumping and greenhouse climate control in agricultural businesses.
- Support rooftop solar and on-site renewable generation.
- Expand digital energy management for consumption monitoring.

Carbon Footprint Calculation Tools

- Establish a shared digital carbon calculation and reporting platform for Antalya.
- Develop accessible sector-specific calculation tools.
- Establish standardised emissions data collection systems.
- Provide carbon accounting and reporting training.
- Create shared infrastructure for managing supply-chain carbon data.

Access to Green Finance

- Establish advisory mechanisms facilitating access to green loans, grants and incentives.
- Provide information on support from KOSGEB, development agencies, TÜBİTAK, TKDK and international financial institutions.
- Develop low-interest financing for green investment.
- Establish green investment matchmaking programmes between banks and SMEs.
- Support carbon reduction projects through green finance instruments.

Green Production Advisory Support

- Establish sustainable production advisory centres through university–industry cooperation.
- Assess SME energy, water and resource efficiency.
- Develop technical support for circular economy and industrial symbiosis.
- Provide sector-specific mentoring and practical training.
- Disseminate good practices demonstrated in pilot businesses.

Carbon Management Guides for SMEs

- Prepare sector-specific guides tailored to Antalya.
- Clearly define required data and calculation procedures.
- Develop practical guidance for energy-, water-, waste- and logistics-related emissions.
- Include cost–benefit analyses of mitigation measures.
- Prepare tailored roadmaps for tourism, agriculture, logistics and manufacturing.

Institutional and Regional Structures

- Establish an Antalya Green Transition Centre.
- Strengthen cooperation among universities, professional chambers, development agencies, OIZs and local authorities.
- Develop SME sustainability and carbon management certification programmes.
- Implement pilot transition projects in tourism and agriculture.
- Establish sustainable production networks and knowledge-sharing platforms across Antalya.

Conclusion

Integrating SMEs into the green transition is critical to Antalya's sustainable development, international competitiveness and climate objectives.

- The proposed measures could:
- Substantially reduce SME energy costs;
- Reduce carbon emissions;
- Expand renewable energy use;
- Improve resource efficiency;
- Facilitate alignment with international supply chains;
- Strengthen access to green finance; and
- Increase export capacity and competitiveness.

For Antalya's SMEs, the green transition should be recognised as a strategic opportunity for economic resilience, investment attraction and sustainable growth.

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4.4. Exports and Carbon Regulations

Scope and Current Situation

The EU Carbon Border Adjustment Mechanism (CBAM) is a climate policy instrument designed to apply a fair carbon price to emissions embedded in imported carbon-intensive products. Its transitional phase began on 1 October 2023, followed by the definitive phase in 2026. Its initial scope covers cement, iron and steel, aluminium, fertilisers, electricity, hydrogen and selected precursor products [1].

While reporting was the principal transitional obligation, from 2026 EU importers or indirect customs representatives must declare embedded emissions and surrender the corresponding CBAM certificates. Certificate prices are linked to the EU ETS carbon price. A documented carbon price paid during production outside the EU may be deducted [1]. Although the obligation to purchase certificates generally rests with EU importers, Turkish exporters face growing pressure to provide reliable emissions data, establish verification arrangements and adopt low-carbon production.

For Antalya, the issue extends beyond industrial products directly covered by CBAM. According to the Antalya Provincial Directorate of Agriculture and Forestry, provincial exports totalled approximately USD 2.2 billion in 2024, including USD 1.2 billion from agriculture, or approximately 56%. Industry and mining contributed approximately USD 956 million [3]. Antalya also accounted for USD 680 million of Türkiye's fresh fruit and vegetable exports and USD 58 million of ornamental plant exports in 2024 [3]. These figures indicate that direct CBAM exposure is concentrated in industry, mining, metals, aluminium, cement, fertilisers and energy-intensive production. Indirect carbon risks are concentrated in agriculture, protected cultivation, cold chains, packaging, logistics and supply chains.

Green supply chains are becoming increasingly important for exporters. Expectations concerning sustainability reporting, corporate sustainability due diligence, Scope 3 emissions and supplier performance are increasing in the EU. The GHG Protocol Scope 3 Standard provides a principal framework for calculating value-chain emissions and identifying reduction priorities [5]. ISO 14064-1 provides an international standard for organisational greenhouse gas quantification and reporting, supporting verification [6]. Antalya's export competitiveness will therefore increasingly depend on measurable, verifiable and low-carbon production alongside product quality and price.

Identification of Problems

The following issues constrain Antalya's alignment with CBAM and green supply-chain requirements:

- Sector- and product-level CBAM risk mapping is not yet sufficiently systematic.
- Organisational and product carbon footprints, energy consumption and supplier emissions data are often not maintained in consistent, verifiable and comparable formats.
- SMEs have limited access to energy monitoring, digital data management, emissions software, sustainability reporting and verification services.
- Energy-intensive industrial and mining processes, electricity consumption, fossil fuel use, process emissions and logistics increase cost exposure.
- Green supply-chain expectations are insufficiently reflected in supplier contracts, procurement criteria and performance indicators.
- Access to suitable finance, public support and technical advice is fragmented. Existing instruments, including TÜBİTAK 1831/1832 and KOSGEB's Green Industry Support Programme, require wider uptake among Antalya's exporters [8], [9], [10].

- Stronger institutional coordination is required. Shared data, training, advice and monitoring infrastructure among BAİB, ATSO, ANSİAD, OIZs, municipalities, universities and public institutions is essential to accelerating business transition.

Proposed Solutions

The following measures could enable Antalya to contribute concretely to the COP31 process:

- **Prepare an Antalya CBAM and Green Export Risk Inventory.** Include indicators covering sectors, product groups, EU market dependence, energy intensity, emissions calculation capacity, supply-chain vulnerability and financing needs.
- **Establish sectoral risk classifications.** Industry and mining, production linked to metals, aluminium, cement and fertilisers, and energy-intensive businesses could be classified as high risk. Fresh produce, ornamental plants, food and protected cultivation could be classified as having moderate indirect risk, while low-energy-intensity services and trade could be treated as lower-risk activities requiring monitoring. Update classifications regularly using BAİB and TİM data.
- **Launch a corporate carbon accounting and verification programme.** Provide shared training and advice on ISO 14064-1- and GHG Protocol-based inventories, product footprints, energy analysis and supplier data collection.
- **Establish an Antalya Green Supply Chain Protocol.** Include supplier emissions declarations, energy efficiency criteria, environmental procurement requirements, packaging reduction, logistics optimisation, recycled inputs and traceability.
- **Create a CBAM Compliance Help Desk.** With contributions from ANSİAD, BAİB, ATSO, Süleyman Demirel University, Akdeniz University and relevant public institutions, provide one-stop guidance on product coverage, emissions data formats, communication with EU customers, verification and support applications.
- **Identify priority green investments.** Priorities in industry and mining should include energy efficiency, renewable energy, waste heat recovery, electric equipment and cleaner production. Agricultural priorities should include greenhouse and irrigation efficiency, fertiliser optimisation, cold-chain efficiency, low-carbon packaging and logistics.
- **Strengthen access to green finance.** Promote the Ministry of Trade's Responsible Programme, KOSGEB's Green Industry Support Programme, TÜBİTAK's 1831 Green Innovation Technology Mentorship Call and 1832 Green Transformation in Industry Call. Establish application schedules and project pipelines for eligible businesses [8], [9], [10].
- **Launch sectoral pilots.** Initially select 5–10 leading businesses across industry/mining, protected cultivation, fresh produce packing, ornamental plants and logistics to prepare carbon inventories, energy audits, supplier data systems and green investment roadmaps.
- **Develop an Antalya Green Export Monitoring Dashboard.** Track sectoral exports, EU market shares, carbon risks, companies preparing inventories, verified companies, support uptake and mitigation projects.
- **Announce an Antalya Green Export Commitment during COP31.** Establish a shared local call for exporters to measure emissions, increase energy efficiency investment, improve supply-chain transparency and use green finance.

Conclusion

CBAM and green supply-chain requirements are strategic determinants of Antalya's export competitiveness as well as compliance matters. Its diverse agricultural, industrial and mining export base requires direct and indirect carbon risks to be addressed together.

The proposed actions could reduce EU market access risks, improve preparedness for carbon costs, strengthen energy and resource efficiency, expand green finance and position Antalya as a leading low-carbon export destination during COP31.

The objective is to develop a competitive production and export ecosystem that measures, reports, reduces and verifies emissions and integrates into green supply chains, extending beyond a defensive compliance approach.

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5. Energy Efficiency and Carbon Emission Reduction in Transport

Scope and Current Situation

Transport accounts for approximately one-quarter of global greenhouse gas emissions and is a priority sector for climate action. In Antalya, tourism, summer population growth, daily travel to the city centre and high private vehicle use increase transport energy consumption and carbon emissions.

Intensive movement between Antalya Airport, tourism areas, the city centre, ports and agricultural production areas reinforces the need for low-carbon transport. Despite investment in rail and public transport, high private vehicle use creates substantial traffic, fuel consumption and air pollution pressures.

Electric vehicles, electric public transport, cycling, micromobility and intelligent transport systems are widely recognised as key instruments for urban carbon neutrality. Antalya must accelerate transport energy efficiency and decarbonisation to support sustainable tourism.

Priority transition areas are:

- Developing electric vehicle infrastructure;
- Electrifying urban transport;
- Expanding cycling and micromobility;
- Strengthening public transport; and
- Implementing low-carbon transport in tourism areas.

Identification of Problems

Electric Vehicle Infrastructure

- Charging station numbers and distribution are insufficient despite growing electric vehicle use.
- Infrastructure is unevenly distributed between tourism areas, rural locations and districts.
- Fast charging remains limited.
- Range anxiety persists.
- Charging energy management and renewable integration are underdeveloped.

Urban Transport Electrification

- Fossil-fuel vehicles dominate public transport fleets.
- Electric buses and low-emission public transport have limited uptake.
- Supporting energy and charging infrastructure are inadequate.
- The grid requires preparation for increasing vehicle-related demand.

Cycling and Micromobility

- Cycle routes do not form a continuous, integrated network.
- Secure bicycle parking is insufficient.
- Integration with public transport is limited.
- Shared bicycle and scooter systems are insufficiently deployed.
- Motor vehicles are widely used even for short journeys.

Strengthening Public Transport

- Public transport's modal share remains below the desired level.
- Connections between tourism areas and the city centre are periodically insufficient.
- Rail network coverage is limited.
- Energy efficiency measures in public transport vehicles are insufficiently adopted.

- Integration between modes is incomplete.

Low-Carbon Transport in Tourism Areas

- Dependence on private vehicles and transfer services is high.
- Airport–tourism area connections rely heavily on carbon-intensive transport.
- Hotels and tourism facilities have limited electric mobility infrastructure.
- Pedestrian- and cycle-friendly planning is underdeveloped.
- Low-emission transport zones have not been implemented.

Proposed Solutions

Developing Electric Vehicle Infrastructure

- Expand fast and ultra-fast charging networks across Antalya.
- Prioritise airports, coach terminals, marinas, shopping centres and tourism areas.
- Require charging infrastructure in new parking facilities and large developments.
- Encourage solar-supported charging stations.
- Develop digital navigation and reservation systems for electric vehicle users.

Urban Transport Electrification

- Accelerate municipal bus fleet electrification.
- Introduce incentives for electric minibuses and shuttle vehicles.
- Expand rail investment to increase low-carbon public transport capacity.
- Aim to supply electric public transport from renewable sources.
- Optimise charging through smart energy management.

Expanding Cycling and Micromobility

- Establish a continuous, safe citywide cycle network.
- Integrate cycling routes with public transport.
- Expand shared electric bicycles and scooters.
- Encourage micromobility at universities, public institutions and tourism areas.
- Increase bicycle parking and secure storage.

Strengthening Public Transport

- Expand rail networks and plan new lines.
- Extend energy efficiency measures across public transport fleets.
- Optimise traffic management through intelligent transport systems.
- Fully integrate public transport, cycling and micromobility.
- Improve accessibility through integrated fare cards and digital mobility platforms.

Low-Carbon Transport in Tourism Areas

- Establish electric public transport connections between the airport, tourism areas and city centre.

- Encourage hotel charging stations.
- Introduce electric shuttles and minibuses in tourism areas.
- Establish pedestrian- and cycling-priority corridors.
- Pilot low-emission zones and car-free tourism areas.
- Include transport-related carbon reduction criteria in sustainable tourism certification.

Conclusion

A low-carbon transport transition is strategically important for Antalya's climate action, air quality, energy security and sustainable tourism objectives.

Developing charging infrastructure, electrifying urban mobility, expanding cycling and micromobility, strengthening public transport and introducing low-carbon tourism transport can deliver:

- Substantial transport greenhouse gas reductions;
- Lower fossil fuel consumption;
- Reduced air and noise pollution;
- Less traffic congestion;
- Improved urban quality of life;
- A stronger sustainable tourism identity; and
- Greater energy efficiency and economic savings.

Antalya's low-carbon transport transition will strengthen climate resilience and contribute substantially to sustainable development.

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6. Scaling Up Renewable Energy Investment and Energy Storage Systems

Scope and Current Situation

Scaling up renewable energy investment is a fundamental policy priority for Antalya's 2030 emissions reduction targets, 2050 carbon-neutral city vision, energy supply security and sustainable tourism identity. The global renewable energy transition is accelerating. According to IRENA, global renewable electricity

capacity increased by 692 GW in 2025 to reach 5,149 GW, with solar accounting for approximately three-quarters of this growth. During the same year, 511 GW of solar capacity was commissioned, bringing global installed solar capacity to 2,392 GW [1].

Solar and wind investment has also become the principal driver of electricity capacity growth in Türkiye. According to the Ministry of Energy and Natural Resources, by the end of January 2026, solar accounted for 25,827 MW, or 20.9%, of installed electricity generation capacity, while wind accounted for 14,862 MW, or 12.1%. Combined solar and wind capacity therefore reached 40,689 MW [2]. These figures demonstrate that distributed solar investment in provinces with substantial solar potential, such as Antalya, is an economic and strategic necessity alongside its environmental benefits.

According to the Ministry's Solar Energy Potential Atlas, Antalya is among Türkiye's most favourable regions for solar energy. Annual sunshine duration is approximately 3,000 hours, while annual total global solar irradiation is approximately 1,600–1,700 kWh/m²/year [3]. This provides a strong technical basis for rooftop solar systems, self-consumption-oriented solar investment in tourism facilities, solar-powered agricultural irrigation, energy cooperatives and local government projects.

Antalya's existing energy and carbon profile further reinforces the need for this transition. The current COP31 working draft reports urban greenhouse gas emissions excluding industry of 8,232,919 tCO_2e for the 2019 baseline year, equivalent to 3.28 tCO_2e per capita. It also states that buildings account for 47.7% of total urban emissions. Rooftop solar PV, solar thermal systems, storage and digital energy management are therefore priority mitigation instruments, particularly for buildings and tourism facilities [7].

Rooftop solar PV is among the most readily deployable forms of distributed generation. Houses, apartment buildings, commercial premises, industrial facilities, public buildings, parking areas, shopping centres and schools provide substantial unused surface potential in Antalya. Under local conditions, a 10 kW residential rooftop PV system can generate approximately 15,000–17,000 kWh annually. This can meet a substantial proportion of many households' annual consumption, including appliances, air conditioning and some electric vehicle charging. In apartment buildings, however, the output allocated per household is insufficient for individual residential demand and may meet only communal electricity needs. In detached houses and villas, a system appropriately configured to the roof and façade conditions may meet the dwelling's entire electricity demand and generate a surplus for sale.

The principal advantage of rooftop PV in Antalya is generation at the point of consumption. This minimises transmission and distribution losses, eases summer air-conditioning-related peak demand and reduces business electricity costs. The World Bank's programme to accelerate Türkiye's distributed solar market aims to support approximately 1 GW of distributed capacity and achieve 14 million tonnes of CO_2 emissions reductions [4]. This scale demonstrates that rooftop PV is an important component of national mitigation strategy as well as an individual investment.

Priority locations in Antalya include public buildings, municipal facilities, schools and universities, hospitals, hotels, cold stores, greenhouse businesses, shopping centres and industrial facilities. Antalya OIZ, for example, reportedly has 114 operational unlicensed solar installations with a combined capacity of 93 MW [7]. This model demonstrates the direct contribution of rooftop and business-scale solar investment to regional competitiveness.

Tourism is a critical application area because of its substantial electricity consumption, hot water requirements, cooling loads, lighting and intensive seasonal demand. Increased summer occupancy makes air conditioning, pool pumps, kitchens, laundries, cold storage, lighting and hot water major contributors to hotel energy expenditure. Solar investment should therefore be integrated with energy efficiency, hot water production, heat pumps, battery storage and smart energy management.

In sunny regions such as Antalya, hotel roofs, parking areas, roofs over building services spaces and suitable ancillary areas offer substantial generation potential. Rooftop PV can meet a significant proportion of daytime electricity demand, reducing grid purchases and making energy costs more predictable. However, roof space alone may be insufficient for large hotels. Ground-mounted solar, solar carports and storage should therefore be assessed alongside rooftop systems.

Solar investment also provides competitive advantages through sustainable tourism certification, green hotel criteria, international tour operators' environmental expectations, carbon footprint reporting and guest perceptions. Tourists and corporate travel providers, particularly from European markets, increasingly consider environmental responsibility, emissions reduction, renewable energy and sustainability performance when selecting accommodation. Solar investment should therefore be recognised as a strategic instrument for strengthening Antalya's international sustainable destination identity.

A large-scale local example is the 60 MW grid-connected photovoltaic park developed on 85 hectares in Elmalı. The project supplies a substantial proportion of the associated hotel group's electricity requirements from renewable energy [8]. Such projects demonstrate that tourism businesses can balance their energy needs with renewable generation and contribute to large-scale emissions reduction. Similar models could serve major hotel groups, resorts, golf facilities and accommodation chains across Antalya.

An appropriate implementation model should begin with a detailed energy audit. This should analyse hourly electricity consumption, cooling loads, hot water requirements, kitchen and laundry demand, pump operating hours, lighting and seasonal energy profiles. Roofs, parking areas, open spaces and any suitable land should then be assessed to determine the best investment model. Rooftop PV should take priority where feasible. Where roofs are insufficient or demand is particularly high, ground-mounted systems, storage and arrangements for offsetting consumption against generation at another location should be considered.

Solar carports offer multiple benefits for hotels. They generate electricity while shading vehicles and improving parking comfort. In Antalya's hot summers, they can reduce vehicle interior temperatures and improve user experience. Integration with electric vehicle charging creates important infrastructure for low-carbon tourism transport. Hotels can thereby reduce grid electricity consumption while providing renewable-supported charging for transfer vehicles, guest vehicles and service fleets.

Energy storage is another important technology for increasing renewable energy use in tourism facilities. Hotel electricity demand varies by time of day and occupancy. Surplus daytime solar generation can be stored for evening use, peak periods or grid outages. This improves supply security and cost management. Battery-supported PV is particularly relevant to large resorts, health and spa facilities, conference hotels and year-round accommodation.

Successful renewable investment requires ongoing performance management. Digital monitoring should track systems, regularly analyse generation and consumption, and report emissions reductions. Smart management enables hotels to identify when and how much energy they consume, the proportion supplied by PV, energy-intensive equipment and opportunities for improvement. These data also support carbon footprint reporting, sustainable tourism certification and corporate sustainability reports.

Antalya's agriculture is energy-intensive because of protected cultivation, irrigation pumps, cold stores, packing facilities and processing. In vegetable, fruit, citrus and protected crop production, electricity is a significant cost during production and subsequent storage, cooling, packing and market preparation. Reducing energy costs is therefore strategically important for farm incomes and food supply security.

Agricultural irrigation is particularly significant. Intensive pump use creates seasonal demand peaks, increasing production costs and pressure on local grids. Peak solar generation coincides with increased

irrigation demand in spring and summer, making solar energy a well-matched and efficient solution. Solar irrigation should therefore be regarded as an integrated instrument for climate adaptation, water management, rural development and producer well-being.

Different deployment models are possible. Small producers may use solar systems integrated with individual pumps, while irrigation associations, agricultural development cooperatives and municipalities can develop shared projects for larger areas. A central solar plant can offset irrigation cooperatives' electricity consumption through netting arrangements. Shared finance, public support and municipal–farmer cooperation can make investment accessible to smaller producers.

Solar irrigation investment should be combined with efficient pumps, variable-speed drives, pressure control, drip irrigation and smart scheduling. Installing renewable generation without first improving efficiency can lead to oversized systems and higher costs. The preferred approach is to improve water and energy efficiency first and then meet remaining energy demand with solar power.

Protected cultivation also offers substantial potential. Ventilation, automation, irrigation, misting, fertigation and climate control increase greenhouse electricity demand. Solar integration can reduce costs, particularly for modern greenhouse automation, pumps and cooling equipment. However, rooftop installations require careful assessment of shading, crop yields and light transmission. Where appropriate, agrivoltaic models combining cultivation and generation should be considered instead of conventional rooftop PV.

Agrivoltaic systems, referred to as TarımGES, combine crop and electricity production on the same land. Panel heights, angles and layouts are designed to accommodate agricultural activity. For some crops in Mediterranean climates, controlled shading can reduce heat stress and water use. Antalya pilot projects should therefore investigate citrus, seedling production, medicinal and aromatic plants, forage crops, open-field vegetables and crop groups with low shade tolerance. This approach can support both electricity generation and climate-adapted agriculture.

Cold stores, packing houses and agricultural processing facilities are also important investment locations. Post-harvest cooling and storage are critical to reducing losses in Antalya's substantial fresh produce sector, but require considerable electricity. PV on suitable roofs or land can reduce preservation costs and supply-chain emissions. Renewable investment therefore benefits agricultural logistics and food safety as well as production.

Energy cooperatives enable residents, farmers, tradespeople, small businesses, apartment and residential estate management bodies, local communities and producer associations to participate directly in renewable investment. They provide a democratic model that broadens ownership beyond large capital groups and centralised investors. Local people can become producers and investment partners as well as consumers.

Members jointly establish renewable generation facilities to meet some or all of their electricity needs. This makes costs more predictable and reduces emissions associated with fossil-based electricity. Energy cooperatives can therefore support climate action, local development, supply security, equitable income distribution and public participation.

Antalya offers considerable potential for this model. Tourism, agriculture, services, small industry and housing are major drivers of demand. Cooperatives could serve irrigation groups, agricultural producer associations, small industrial estates, hotel clusters, organised tourism zones, apartment buildings, residential estates, rural neighbourhoods and local businesses.

Structures with shared consumption patterns and similar needs are particularly suitable. Irrigation cooperatives are a clear application: joint solar generation can reduce pumping costs, ease production

pressures and support rural development. Shared access also strengthens social justice by enabling small producers to participate in investments they could not undertake individually.

Small industrial estates and tradespeople also offer opportunities. Furniture, food processing, metalworking, cold-chain, logistics, repair and small manufacturing businesses are directly affected by rising electricity costs. Shared rooftop PV, solar carports or ground-mounted systems could reduce expenditure, lower footprints and strengthen transition capacity.

For tourism, cooperatives could provide joint investment models for hotel clusters, resorts, boutique hotels and other businesses in the same area. Shared ground-mounted generation or regional energy-sharing arrangements could reduce operating costs and strengthen Antalya's sustainable destination identity.

Apartment and residential estate management bodies are another important group. Multi-block estates and large residential developments consume electricity regularly for communal lighting, lifts, booster pumps, pools, security and landscape irrigation. Rooftop PV and shared cooperatives could reduce the energy-related component of service charges while mobilising rooftop potential and public participation.

In Germany and Denmark, energy cooperatives have helped increase public acceptance of renewables. German citizen energy models have enabled local participation in solar and wind projects, while Danish wind cooperatives have supported acceptance through local ownership and revenue sharing.

These examples demonstrate the importance of ownership, participation, income distribution and local acceptance alongside technical infrastructure. Expanding cooperatives in Antalya requires a strong institutional and financial framework, including cooperation among local authorities, chambers of commerce and industry, agricultural chambers, irrigation and tourism associations, development agencies and financial institutions.

Local guidance should support project development, feasibility, permitting, grid connection, finance, engineering, operation and maintenance. Members should also receive training in financial literacy, energy legislation and emissions reduction.

Financing could combine green loans, low-interest investment finance, development agency support, municipality-led joint investment, international climate funds and carbon finance. Affordable membership shares, socially oriented financing and publicly supported guarantees are particularly important for small producers and low-income households.

Cooperatives can thus become instruments for addressing energy poverty as well as generating financial returns. Transparent governance is essential. Digital systems should enable members to monitor generation, consumption, income, expenditure and emissions reductions. Decision-making should be participatory, and revenue-sharing and cost-saving arrangements clearly defined. System performance should be monitored, maintenance professionally managed and mitigation outcomes reported.

Local authorities are major energy consumers and public bodies guiding citywide transition. Municipal buildings, water and wastewater pumping, treatment plants, waste facilities, bus depots, slaughterhouses, markets, sports facilities, parking, social services, irrigation and street lighting consume substantial energy. Municipal renewable investment can reduce public expenditure and demonstrate good practice.

Markets and parking areas are especially suitable. Covered market roofs and solar canopies over open parking areas can generate electricity while creating shaded, comfortable and climate-resilient public spaces. In Antalya, solar carports can also help reduce urban heat and support renewable-powered vehicle charging.

Public transport infrastructure should be planned together with renewable projects. Solar systems on electric bus depots, maintenance buildings and interchanges can support renewable charging for buses and

municipal vehicles. Solar-supported charging could be planned at the airport, coach terminal, rail stops, bus storage facilities and municipal fleet sites.

Waste and wastewater treatment facilities are additional priorities. Solar can be combined with biogas, biomass and waste heat recovery. Organic waste digestion, sludge-to-energy and heat recovery integrate circular economy and renewable energy policies. Antalya Metropolitan Municipality's biomass and waste heat recovery facilities could provide scalable local models.

Municipalities can also cooperate with irrigation groups and producer associations on rural solar projects, reducing farm costs and supporting rural development and energy poverty reduction. Solar applications in social housing, public bread production facilities, nurseries, older people's care centres and social assistance facilities can reduce communal and public service electricity expenditure.

Identification of Problems

Technical, financial, regulatory and institutional barriers include:

- Limited grid connection capacity and substation suitability in many areas.
- Low awareness of residential rooftop PV and weak technical advice, structural assessment and collective decision-making.
- Insufficient energy audits, consumption profiling and solar-plus-storage feasibility studies in tourism facilities.
- Limited financing access for irrigation associations and cooperatives despite high consumption.
- Insufficient understanding of cooperative legislation, accounting, operating models and connection procedures.
- Limited municipal budgets, technical staffing and project development capacity.
- Absence of a citywide rooftop potential inventory, consumption map and digital renewable monitoring platform.
- Storage, smart metering, demand-side management and microgrids remaining largely at pilot stage.

Proposed Solutions

Antalya Rooftop Solar Deployment Campaign

- Prepare an Antalya Rooftop PV Inventory covering public buildings, schools, hospitals, municipal facilities, OIZ roofs, hotels and commercial buildings.
- Use satellite imagery and GIS to assess suitable roofs, shading, indicative capacity and generation potential.
- Prepare standard feasibility guides for typical 10 kW residential, 100 kW commercial and 1 MW industrial/tourism projects.
- Require solar-ready roofs, cable routes, inverter space and vehicle charging infrastructure in new building permits.

Solar Energy and Carbon Reduction Programme for Tourism Facilities

- Make annual energy audits, footprint measurement and renewable roadmaps mandatory or subject to incentives.
- Plan rooftop PV, carports, ground-mounted PV, solar thermal, heat pumps and batteries together.

- Add renewable energy shares, charging infrastructure and mitigation indicators to sustainable tourism certification.
- Develop shared solar and cooperative models for hotel clusters.

Agricultural Irrigation Solar and Floating Solar Pilots

- Establish municipally supported shared investment models for irrigation associations and cooperatives.
- Integrate pump modernisation, drip irrigation, smart automation and solar investment.
- Pilot floating solar on reservoirs following environmental, ecological carrying capacity and grid connection assessments.
- Combine farmer contributions, municipal support, development agency grants and green loans.

Energy Cooperatives and Local Participation

- Prepare separate guides for irrigation groups, industrial estates, residential communities and tourism clusters.
- Provide technical support for development, connections, finance, operation and maintenance.
- Pilot social energy cooperatives and municipally supported shared solar to reduce low-income household costs.

Local Government Renewable Energy Roadmap

- Target at least 50% renewable electricity for metropolitan and district municipal consumption by 2030.
- Prioritise water and wastewater pumping, transport depots, service buildings, markets and parking areas.
- Establish digital platforms monitoring generation, consumption and emissions reductions.
- Use international climate funds, green bonds, energy performance contracts and public–private partnerships actively.

Conclusion

These measures are expected to deliver significant climate, economic and social benefits. By 2030, rooftop, tourism, agricultural irrigation and municipal projects could jointly create hundreds of megawatts of distributed solar capacity. Each 1 MW in Antalya can generate approximately 1.5–1.7 million kWh annually.

Accordingly, 500 MW could theoretically generate approximately 750–850 million kWh of clean electricity annually. Benefits would include lower bills, reduced dependence on imported fossil fuels, a stronger green tourism identity, lower irrigation costs and reduced municipal expenditure. Investment would also create skilled local employment in engineering, installation, maintenance, software, energy management and finance.

Proposed measurable performance indicators are:

- New distributed PV capacity by 2030: at least 500 MW.
- Renewable share of municipal electricity: at least 50%.

- Tourism facilities using PV or solar thermal: at least 60%.
- Renewable share of agricultural irrigation electricity: at least 50%.
- Cooperative pilots: at least 10 cooperative or cluster models.
- Digitally monitored consumption/generation points: at least 1,000.

Renewable investment should be central to Antalya's COP31 climate leadership. Its solar resource, tourism and agricultural demand, municipal experience and OIZ infrastructure could establish it as a model distributed renewable energy city.

An integrated approach combining rooftops, tourism, irrigation, cooperatives and municipal projects would reduce emissions and costs, support producers and businesses, strengthen tourism sustainability and create new investment opportunities.

The COP31 Antalya approach should combine data-driven planning, participation, diverse finance, digital monitoring and sector-specific guidance, positioning Antalya as a leading Mediterranean example of climate-resilient, low-carbon urban development.

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7. Green Hydrogen Potential

Scope and Current Situation

Green hydrogen is a low-carbon energy carrier produced by electrolysis using renewable electricity. According to IRENA, declining renewable costs are accelerating the deployment of renewable-powered hydrogen technologies.

Türkiye regards green hydrogen as strategic for reducing energy imports and industrial decarbonisation. Applications include steel, fertilisers, petrochemicals and refining, alongside fuel-cell solutions for heavy vehicles, buses, shipping and rail. The Ministry's Türkiye Hydrogen Technologies Strategy and Roadmap defines relevant actions [4]. Targets include reducing production costs below USD 2.4/kgH_2 by 2035 and USD 1.2/kgH_2 by 2053, and increasing electrolyser capacity to 2 GW by 2030, 5 GW by 2035 and 70 GW by 2053.

One concrete initiative is HYSouthMarmara, developed by a 16-member international consortium coordinated by the South Marmara Development Agency. Supported through the Horizon Europe Clean Hydrogen Partnership's 2022 call, the five-year project aims to establish Türkiye's first Green Hydrogen Valley [5].

The Mediterranean offers substantial production potential under EU hydrogen strategies. Antalya's sunshine, renewable capacity and port connections give it a strategic position. Hotels could become future users through footprint reduction, sustainable energy certification and green transition objectives. Large resorts, marinas and airport logistics are potential applications. Greenhouse production, irrigation and agricultural cold chains could also integrate renewable-powered hydrogen production and storage, supporting continuity and reduced diesel dependence.

Port equipment conversion to fuel cells, shore-side electrification and future hydrogen-derived logistics fuels offer additional opportunities. OIZs, cold stores and agricultural logistics facilities could use hydrogen for storage and backup power. Planning must also consider electrolysis water requirements, including treated wastewater and alternative sources.

Identification of Problems

- Hydrogen infrastructure is insufficiently developed.
- Investment costs are high.
- Technical expertise is limited.
- Renewable–hydrogen integration is restricted.
- Regulation remains under development.
- Sustainable electrolysis water management requires assessment of treated wastewater and desalination alternatives.

Proposed Solutions

- **Pilot Green Hydrogen Projects:** Develop pilots at ports, OIZs and tourism facilities.
- **Solar-Powered Electrolysis:** Utilise the region's substantial solar potential.
- **Industrial and Transport Integration:** Support hydrogen in heavy transport and industrial processes.
- **University–Industry Research:** Establish hydrogen research infrastructure.

Conclusion

The proposed measures could accelerate low-carbon transition, increase renewable energy use and strengthen supply security.

Antalya's renewable resources and strategic location provide potential for leadership in hydrogen development and deployment. Green hydrogen should therefore be assessed as a strategic technology supporting sustainable development, energy security and the low-carbon economy.

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8. Circular Economy and Energy

Scope and Current Situation

The circular economy is a sustainable development model based on reducing resource use, recovering value from waste and recovering energy.

Antalya generates substantial quantities of organic waste from tourism, agriculture and services. This creates significant opportunities for biogas, waste-to-energy generation and organic waste recovery systems.

According to OECD data, circular economy practices can substantially improve resource efficiency at city scale.

Identification of Problems

- Most organic waste is sent to landfill.
- Waste-to-energy capacity is limited.
- Source separation systems are insufficiently deployed.
- Technical capacity for biogas investment is inadequate.
- Financing mechanisms are limited.

Proposed Solutions

- **Waste-to-Energy Generation:** Municipal and tourism-related organic waste should be utilised for energy production.
- **Regional Biogas Facilities:** Energy generation from agricultural residues and animal waste should be supported.
- **Organic Waste Separation:** Mandatory separation systems should be established for hotels and large businesses.
- **Zero Waste Policies:** Locally supported recycling and waste prevention policies should be strengthened.

Conclusion

The proposed measures could:

- Reduce methane emissions;
- Increase energy generation capacity;
- Reduce the burden on landfills; and
- Improve resource efficiency.

Circular economy practices will be an important instrument supporting Antalya's sustainable energy transition.

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9. Local Government Energy Policies

Scope and Current Situation

Local authorities are key implementing actors in city-level climate action. Municipalities influence direct and indirect greenhouse gas emissions through buildings, transport, waste management, drinking water and wastewater services, street lighting, park and garden irrigation, zoning and urban regeneration decisions, disaster management, digital infrastructure and public procurement. Municipal energy policy should therefore be treated as an integrated field of governance combining citywide carbon management, renewable energy investment and smart city applications.

An important institutional framework for national climate policy is emerging in Türkiye. The Climate Change Mitigation Strategy and Action Plan (2024–2030) and Climate Change Adaptation Strategy and Action Plan (2024–2030), published by the Directorate of Climate Change, establish the national direction for mitigation and adaptation [1]. Climate Law No. 7552 provides for local climate change action plans to be prepared as integrated provincial plans, with direct metropolitan municipality involvement in metropolitan provinces and submission to Provincial Climate Change Coordination Boards [2]. This requires municipalities to strengthen their energy, carbon, data and investment management capacity.

Antalya's circumstances demonstrate the potential to link local energy policies directly to the COP31 process. Antalya Metropolitan Municipality signed the Covenant of Mayors in 2013, undertook organisational and citywide greenhouse gas inventories, and established a target under its Sustainable Energy Action Plan to reduce per capita emissions by approximately 40% by 2030 relative to 2019 [3]. Antalya's tourism, agriculture, port, free zone, organised industry, transport and rapid population growth require municipal energy policies to address citywide demand, mitigation, monitoring and resilience alongside municipal buildings.

Renewable energy in municipal buildings provides a visible and measurable area for transition. Administrative buildings, social facilities, cultural centres, coach terminals, water and wastewater facilities, wholesale market complexes, sports facilities and parking areas are suitable for rooftop PV, efficient lighting, heat pumps, automation, monitoring software and storage. These investments reduce municipal costs and demonstrate good practice to residents and businesses.

Smart city energy management provides the principal means of making municipal mitigation capacity data-driven. The draft framework for the National Smart Cities Strategy and Action Plan (2024–2030) emphasises advanced technology, sustainability and resilience. It seeks balanced resource use and greater resilience to environmental and social shocks through digitalisation, AI-enabled sensors and smart city applications [4]. Smart meters, IoT monitoring, GIS, building energy management, smart lighting, water loss monitoring, vehicle charging and citywide carbon dashboards should therefore become core components of municipal energy policy.

Identification of Problems

The following issues are particularly significant:

- Organisational carbon footprints and citywide inventories are often unsupported by regularly updated, verifiable and comparable datasets.
- Energy consumption is monitored separately across buildings, park lighting, water and wastewater facilities, transport, social facilities and municipal companies, without consistently integrated management.
- Despite substantial potential, audits, automation, LED upgrades, insulation and renewable investment are not incorporated into comprehensive investment programmes.
- Rooftop PV, solar carports, renewables at water and wastewater facilities, and generation on suitable municipal land require wider deployment.
- Smart city projects commonly focus on transport, security, infrastructure or resident services without sufficient links to energy efficiency, mitigation and adaptation indicators.
- Municipal information systems, GIS, meter readings, fleet records, building consumption and carbon calculations are insufficiently integrated.
- Institutional capacity requires strengthening in financing, feasibility, payback assessment, maintenance and performance monitoring.
- Citywide carbon management is weakened where metropolitan and district municipalities lack systematic data sharing, common standards, shared indicators and coordinated investment priorities.
- Continuous, data-driven participation involving residents, businesses, OIZs, tourism facilities, universities and professional chambers is insufficiently institutionalised.

Proposed Solutions

The following measures could establish a visible, measurable and implementable municipal energy policy model during COP31:

- **Municipal Carbon Management System:** Define organisational footprints, citywide inventories, annual mitigation targets, sectoral data collection and monitoring schedules for metropolitan and district municipalities. Methods could align with national strategies, IPCC methodologies, the GHG Protocol and local climate action planning requirements.
- **Antalya Local Energy and Carbon Dashboard:** Monitor buildings, lighting, water and wastewater facilities, fleets, renewable generation, charging and efficiency investment through one digital dashboard. Provide a management interface for decision-makers and a simplified public transparency interface.
- **Municipal Building Energy Audit and Renovation Programme:** Prioritise buildings by consumption, usage intensity, rooftop potential, cooling loads, maintenance needs and payback. Initial priorities could include high-consumption administrative, social, sports and cultural facilities, terminals, wholesale markets and parking areas.
- **Renewable Investment in Municipal Facilities:** Prioritise rooftop PV, solar carports, batteries, heat pumps, solar water heating and efficient lighting. Continuously operating water and wastewater facilities could serve as pilots.

- **Smart Lighting and Energy-Efficient Public Spaces:** Introduce LEDs, scheduling, motion and occupancy sensors, remote monitoring and fault management in streets, parks, waterfronts, squares and walking routes to reduce energy and maintenance costs.
- **Climate-Aligned Smart Energy Management:** Require indicators for electricity savings, CO_2e reductions, renewable generation, water savings, demand and occupancy management, and disaster and climate resilience alongside service quality and digitalisation.
- **Low-Carbon Municipal Fleets:** Develop electric and hybrid transition schedules for service, public transport support, maintenance and light commercial vehicles. Integrate charging with municipal buildings, parking, tourism areas and interchanges.
- **Green Procurement and Low-Carbon Tendering:** Include energy ratings, life-cycle costs, carbon footprints, recycled content, maintenance efficiency and product lifetimes in procurement specifications.
- **Common Standards and Capacity Building:** Under metropolitan coordination, provide district municipalities with joint training and guidance on carbon accounting, energy management, renewable feasibility, smart city data and climate action planning.
- **Financing and Project Pipeline:** Combine municipal budgets, national support, development agency programmes, international climate finance, energy performance contracts and public–private partnerships. Record investment costs, expected savings, mitigation, payback and social benefits for each project.
- **Antalya Local Government Energy Policies Pilot Programme for COP31:** Select municipal buildings, smart lighting areas, renewable facilities and digital monitoring applications as demonstration projects. Report technical outcomes and communication value and share them with national and international stakeholders.

Conclusion

Local energy policy is an agenda for economic efficiency, institutional capacity, technological transition and urban resilience as well as environmental protection. Integrating municipal carbon management, renewable investment and smart energy systems can reduce costs and emissions, improve public services and strengthen climate resilience.

Antalya's existing energy action planning and 2030 mitigation target provide an important foundation. COP31 offers an opportunity to develop a data-driven, investment-oriented, measurable and transparent model covering metropolitan and district municipalities. This should unite municipal renewables, smart management, citywide carbon data and shared implementation capacity.

Antalya could thereby demonstrate how local authorities can manage energy transition in a metropolitan area under intensive tourism, agricultural, industrial and urban pressures. Municipalities would become leading institutions that reduce their own emissions and guide wider low-carbon transformation.

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10. Carbon Markets and Financing

10.1. Voluntary Carbon Markets

Scope and Current Situation

Carbon markets are recognised as key market instruments for implementing the Paris Agreement and achieving global net-zero emissions. Carbon pricing and credit markets assign economic value to mitigation investment and increase private-sector participation in climate finance.

According to the World Bank's *State and Trends of Carbon Pricing 2026*, 87 implemented carbon pricing policies, including ETSs and carbon taxes, cover approximately 29% of global greenhouse gas emissions [World Bank, 2026, p. 5]. Coverage has more than doubled from approximately 12% in 2016 [World Bank, 2026, pp. 5–9].

Climate Law No. 7552 explicitly defines voluntary carbon markets in Turkish legislation for the first time as markets where carbon credits are bought and sold voluntarily [7552 Sayılı İklim Kanunu, Article 2/i].

The Law defines a carbon credit as a credit representing one tonne of CO_2 equivalent, generated through independent verification and certification by standards organisations of greenhouse gas reduction or removal activities [7552 Sayılı İklim Kanunu, Article 2/ö].

These definitions incorporate voluntary markets and credit mechanisms into a comprehensive national climate framework.

Work under Article 6 of the Paris Agreement has substantially clarified international carbon market arrangements. The World Bank identifies Article 6 provisions following COP29 as the principal operational framework [World Bank, 2026, p. 9].

Current Market Trends (2024–2026)

Carbon credit issuance increased by 8% between 2024 and 2025 [World Bank, 2026, p. 6].

The report states that:

- Issuance increased by 8% in 2025 relative to 2024;
- Government-supported crediting mechanisms increased from 24 to 34 over ten years; and
- More than 80% of credit use remains voluntary [World Bank, 2026, p. 6].

Approximately USD 12 billion in forward carbon credit offtake agreements was signed in 2025, indicating future demand [World Bank, 2026, p. 6].

Strategic Importance for Türkiye

Potential credit-generating activities supporting net zero include:

- Renewable energy;
- Afforestation and reforestation;
- Agricultural carbon sequestration;
- Waste management and biogas; and
- Energy efficiency.

The Law's definition of international carbon markets also provides a legal foundation for future Article 6 integration [7552 Sayılı İklim Kanunu, Article 2/ff].

Identification of Problems

- A national voluntary market registry has not yet been established.
- Double-counting risks remain.
- Carbon project expertise is insufficient.
- SMEs struggle with development costs.
- Quality and credibility concerns persist.
- National rules require alignment with international standards.

Proposed Solutions

- Establish a national voluntary carbon market registry.
- Develop digital monitoring, reporting and verification (MRV).
- Use internationally aligned methodologies.
- Support municipal carbon project development.
- Introduce dedicated incentives for agriculture, forestry and blue carbon.
- Clearly define relationships between Türkiye's ETS and voluntary markets.

Conclusion

Voluntary markets can mobilise additional climate finance beyond public budgets. World Bank data indicate continued growth and increasing demand for projects with high environmental integrity [World Bank, 2026, p. 6].

For Türkiye, they offer opportunities for net zero, rural development, natural sink protection and international climate finance.

10.2. Carbon Credit Mechanisms

Scope and Current Situation

Carbon credit mechanisms enable the measurement, verification, certification and trading of reductions or removals. They operate in voluntary markets and, under specified conditions, compliance markets.

Unlike Kyoto-era mechanisms, Article 6 enables cooperation under nationally determined contributions (NDCs) and international transfers of mitigation outcomes. Following COP29, it has become the principal international market governance framework [World Bank, 2026, p. 9].

Credits are used for voluntary offsetting, international aviation under CORSIA, international cooperation and offsetting in some ETSs.

Climate Law No. 7552 explicitly defines credits as independently verified and certified reductions or removals representing one tonne of CO_2 equivalent [7552 Sayılı İklim Kanunu, Article 2/ö].

It also defines offsetting and provides for credit use under the ETS or voluntary commitments [7552 Sayılı İklim Kanunu, Article 2/f], indicating potential integration.

Global Trends and Post-COP29 Developments

Credit issuance increased by 8% between 2024 and 2025 [World Bank, 2026, p. 6].

The report states that:

- Crediting mechanisms increased from 24 to 34 over ten years;
- Voluntary retirements exceed 80% of total use; and
- Approximately USD 12 billion in forward purchase agreements was concluded in 2025 [World Bank, 2026, p. 6].

The first Paris Agreement Crediting Mechanism (PACM) credits were provisionally issued for a clean cooking project in Myanmar, indicating initial operationalisation of Article 6.4 [World Bank, 2026, p. 6].

CORSIA-eligible credits traded at USD 15–22 per tonne in 2025, attracting a premium over many other credit categories [World Bank, 2026, p. 6].

Relationship between Türkiye's ETS and Carbon Credits

Climate Law No. 7552 establishes the legal basis for an ETS, defined as a market-based mechanism that caps emissions consistently with net zero and encourages reductions through allowance trading [7552 Sayılı İklim Kanunu, Article 2/g].

The draft regulation provides that:

- The ETS uses an emissions-intensity-based cap [TR ETS Taslağı, Article 11];
- Category B and C installations are covered [TR ETS Taslağı, Article 5]; and
- Credits may be used for offsetting [TR ETS Taslağı, Article 4/10].

These provisions indicate potential combined use of trading and crediting.

Identification of Problems

- Article 6 institutional capacity remains under development.

- Credits must be linked to national inventories and NDCs.
- Technical infrastructure for double-counting prevention is required.
- ETS credit use rules remain undefined.
- National removal methodologies are absent.
- Specialist workforce needs persist.

Proposed Solutions

- Establish a national carbon credit registry.
- Create Article 6 authorisation arrangements.
- Define ETS offset rules clearly.
- Develop national removal methodologies.
- Establish digital MRV and transaction records.
- Strengthen university–government–business cooperation.
- Consider a regional carbon market capacity-building centre under COP31.

Conclusion

Carbon credit mechanisms are strategically important for mobilising finance towards Türkiye's 2053 net-zero target. International markets continue to expand, while Paris Agreement mechanisms are becoming operational [World Bank, 2026, pp. 6–9].

Compatible ETS and crediting infrastructure could support national mitigation and greater access to international finance.

10.3. Green Financing Instruments

Scope and Current Situation

Carbon pricing alone cannot finance the investments required for energy transition, industrial decarbonisation, sustainable transport, circularity, natural sinks and adaptation. Market effectiveness therefore depends on developed green financing instruments.

Climate Law No. 7552 defines climate finance as local, national or international funding from public, private and alternative sources supporting mitigation and adaptation [7552 Sayılı İklim Kanunu, Article 2/m].

It defines Türkiye's Green Taxonomy as a classification system establishing principles and criteria for climate-supporting economic activities to mobilise finance [7552 Sayılı İklim Kanunu, Article 2/çç].

These provisions establish a legal basis for coordinated carbon market and financing development.

Global Financing Needs and Trends

Climate financing needs are increasing rapidly, and pricing revenues meet only part of them.

Public ETS and carbon tax revenues exceeded USD 107 billion in 2025 [World Bank, 2026, p. 5], compared with less than USD 30 billion in 2016 and annual revenues above USD 100 billion after 2021.

Meanwhile, fossil fuel subsidies exceeded USD 900 billion in 2024 [World Bank, 2026, p. 11], demonstrating continued substantial support for carbon-intensive activities.

Forward credit investment commitments reached approximately USD 12–16 billion in 2025, indicating continuing private interest [World Bank, 2026, p. 11].

Green Financing Instruments for Türkiye

Priority investment areas for 2053 include:

- Renewables;
- Energy storage;
- Grid modernisation;
- Industrial decarbonisation;
- Green hydrogen;
- Sustainable transport;
- Circular economy applications; and
- Adaptation infrastructure.

The Law defines carbon pricing instruments to include ETSs and carbon-based taxes [7552 Sayılı İklim Kanunu, Article 2/o] and authorises the Directorate to regulate pricing mechanisms [Article 4/2]. This establishes institutional foundations for directing future revenues towards climate investment.

Strategic COP31 Opportunities

1. Allocating ETS Revenues to Climate Investment

Revenues can support industrial transition, efficiency, renewables, just transition and adaptation. International practice directs substantial revenues back towards climate investment [World Bank, 2026, p. 5].

2. Implementing Türkiye's Green Taxonomy

The taxonomy can guide sustainable investment, develop green bond markets, support bank climate risk management and facilitate international investment.

3. Accessing International Climate Finance

Türkiye can mobilise funding through the Green Climate Fund, multilateral development banks, blended finance and carbon market revenues.

4. Municipal Finance

Municipal access should be improved for efficiency, zero waste, sustainable transport, water management and adaptation projects.

Identification of Problems

- Long-term finance is insufficient.
- SME access is limited.
- Municipal project preparation capacity is weak.
- Carbon market and financing integration remains undeveloped.

- Climate risk pricing is limited.
- Taxonomy implementation infrastructure is nearing completion.

Proposed Solutions

- Earmark a share of ETS revenues for climate investment.
- Implement the taxonomy promptly.
- Develop affordable SME transition loans.
- Support municipal project preparation.
- Encourage green bonds and sustainable finance.
- Coordinate carbon markets and financing policies.
- Consider a regional climate finance platform under COP31.

Conclusion

Carbon markets and green finance are complementary. Pricing revenues now exceed USD 107 billion annually [World Bank, 2026, p. 5].

An integrated ETS, crediting framework and taxonomy could support low-carbon development, industrial transformation and international financing access. Coordinated action during COP31 could advance Türkiye's role as a regional climate finance centre.

Methodological Note

All numerical data in this section were verified against the uploaded World Bank *State and Trends of Carbon Pricing 2026* report or Climate Law No. 7552. Secondary data from OECD finance reports, Climate Bonds Initiative reports and COP29 NCQG decisions were excluded because direct source verification was unavailable. The final COP31 report should verify these primary sources and incorporate them where needed.

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11. Energy Poverty

11.1. General Introduction

Energy poverty is the inability of individuals and households to access adequate, reliable, clean and affordable energy services, or an excessive energy expenditure burden relative to income. It is a multidimensional development challenge connecting social well-being, energy security, public health, air quality, climate change and just transition.

Türkiye must accelerate its transition towards the 2053 Net-Zero Emissions Target without increasing energy poverty. A balanced policy is required to reduce coal and other fossil fuel use in low-income households while protecting access.

This report considers household access, cost reduction and social support while integrating coal phase-out and just transition perspectives.

11.2. Energy Access in Low-Income Households

Scope and Current Situation

Access means reliable, continuous, clean and affordable services, beyond an electricity connection.

Although electricity access is widespread in Türkiye, low-income households devote substantial income to heating, hot water and electricity. Affordability and clean energy access remain major concerns.

Wood, coal, lignite and other solid fuels remain in use, particularly in rural areas, smaller settlements and low-income groups. Despite short-term financial advantages, they increase emissions, impair air quality and accelerate climate change.

Residential fossil fuel use must decline under the 2053 target, with safeguards for low-income households.

Identification of Problems

- Energy expenditure occupies a high share of low-income budgets.
- Inefficient homes and appliances increase costs.
- Solid fuel use continues in some areas.
- Clean technology access varies with income.
- Rural transition investment may be limited.

- Older people, disabled people and vulnerable groups are disproportionately affected by price increases.
- Rising and variable temperatures increase demand for both heating and cooling.

Proposed Solutions

- Define and regularly measure energy poverty nationally.
- Map household energy use and its emissions impact.
- Identify inefficient appliances and accelerate replacement.
- Develop efficient housing programmes for low-income households.
- Expand fossil-free heating in social housing.
- Integrate rooftop solar into social housing.
- Provide clean energy transition programmes, awareness and accessible long-term finance in coal-dependent areas.
- End wood and coal distribution through social assistance.
- Support rural renewable solutions.

Conclusion

Assessment from a 2053 Perspective

During 2025–2030, map energy poverty and coal use, identify energy service needs and introduce rules preventing non-clean and non-renewable energy use in new buildings.

During 2030–2040, transition all new homes to clean renewable energy and develop projects and financing for existing energy-poor and social housing.

During 2040–2050, complete the transition of all pre-2030 homes that do not meet their needs through clean renewable energy.

11.3. Reducing Energy Costs

Scope and Current Situation

High energy costs relative to income are a principal cause of energy poverty. Price volatility disproportionately affects low-income households.

Coal persists partly because of relatively low upfront costs, but inefficient systems entail higher long-term consumption, health and environmental costs.

Wood, a biomass alternative to fossil fuels, may be relatively sustainable but has a high carbon footprint because of combustion-related greenhouse gases and particulates.

Cost reduction should combine price support with efficiency, insulation, heat pumps, renewables and smart management.

Identification of Problems

- Low-income households struggle to invest in efficiency.
- Old buildings consume substantial energy.

- Coal-using households cannot afford clean alternatives.
- Efficient equipment has high upfront costs.
- Price volatility harms vulnerable groups.
- Social impacts of carbon pricing are insufficiently assessed.

Proposed Solutions

- Provide insulation support.
- Encourage heat pumps and efficient electric heating.
- Support access to efficient appliances.
- Allocate carbon revenues to energy poverty reduction.
- Expand social housing renewables.
- Phase out coal gradually with social safeguards.

11.4. Social Support Mechanisms

Scope and Current Situation

Energy assistance, social tariffs and direct income support are widely used to prevent deprivation.

Türkiye provides support through several programmes, but these must align with long-term transition and net-zero objectives. Coal assistance should progressively evolve into clean energy support.

Identification of Problems

- Social assistance and transition policies are insufficiently integrated.
- Energy poverty data are limited.
- Coal assistance provides short-term relief without supporting transformation.
- Municipal roles are limited.

Proposed Solutions

- Prepare a National Energy Poverty Strategy.
- Redesign assistance to encourage clean energy.
- Integrate support with efficiency investment.
- Direct carbon revenues towards vulnerable groups.
- Consider replacing coal assistance progressively with clean equipment support.
- Strengthen municipal transition assistance.

Conclusion

Transition costs should not fall on low-income households. Support should provide lasting solutions through clean technology access alongside immediate bill assistance.

11.5. Overall Conclusion

Addressing energy poverty is integral to energy and climate policy. Access, affordability and support must be considered alongside coal reduction and clean transition under the 2053 target.

COP31 should address energy poverty through just transition, security, public health and finance as well as social policy. This can support emissions reduction while ensuring an inclusive and equitable transition.

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CHAPTER

03

ANTALYA
2050

ANTALYA 2050 / COP31

CLIMATE-RESILIENT INTEGRATED WATER MANAGEMENT: ANTALYA

WATER SECURITY · EFFICIENCY · INFRASTRUCTURE RESILIENCE

- Water supply security
- Water loss and leakage management
- Water reuse

A Strategy for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

Climate-Resilient Integrated Water Management: Antalya

1. Introduction

Antalya is among the provinces requiring a multidimensional approach to water management because of its karst water resources, coastal aquifers, substantial agricultural production capacity, intensive tourism activity and rapidly developing urban areas. The city's water security must be assessed in relation to groundwater abstraction, water losses, seasonal population and tourism pressures, agricultural irrigation demand, wastewater reclamation opportunities and the effects of climate change on drought–flood cycles, alongside existing water availability. A conventional approach focused solely on developing additional water supplies is therefore insufficient. Existing resources must be protected, demand managed, losses reduced and alternative water sources systematically integrated into supply systems.

This report has been prepared to support the development of climate-resilient integrated water management in Antalya. It addresses water supply security and resource sustainability, urban water management and infrastructure resilience, agricultural water management, water efficiency in tourism and industry, governance, financing and participation arrangements, and decision support mechanisms through an integrated approach. Its central purpose is to establish an implementable and monitorable management framework that strengthens interinstitutional coordination and addresses both current challenges and risks expected to intensify under climate change.

2. Water Supply Security and Resource Sustainability

2.1. Current Situation

Antalya's water supply security is shaped jointly by surface water availability, karst springs, coastal aquifers, groundwater abstraction and seasonal demand fluctuations. The Antalya Basin Drought Management Plan assesses the basin water balance through components including precipitation, external recharge, baseflow, surface runoff, submarine groundwater discharge, evaporation and groundwater abstraction for drinking water supply. According to the plan, total annual inflows and outflows balance at 21,567.75 hm^3/year. However, this balance alone does not adequately safeguard against risks associated with the spatial distribution of groundwater abstraction and pressures on water quality [1].

Antalya's hydrogeology is dominated by karst systems, where interactions between groundwater and surface water cannot always be readily explained using a conventional closed-basin approach. In particular, karst conditions make recharge from outside the basin and spring discharge important considerations. Resource sustainability therefore requires monitoring abstraction, recharge, water quality, coastal influences and ecosystem requirements at sub-basin scale, alongside total annual water availability [1].

Antalya's principal surface water resources include the Düden, Aksu, Köprüçay, Manavgat and Alara rivers. Their flow regimes are reported to be irregular, with substantial reductions during summer [2]. Drinking and domestic water supplies draw on springs, wells and, to a limited extent, reservoirs. Since groundwater supplies most of the water entering drinking and domestic water systems across the province, managing the balance between abstraction and water quality is strategically important, particularly in coastal areas and plains.

Two groundwater risks must be considered together. The first is over-abstraction. The basin plan indicates that agricultural irrigation in some areas depends entirely or predominantly on groundwater and that licensed and cooperative wells account for substantial water allocations [1]. The second is water quality. The Antalya Province Environmental Status Report for 2024 records elevated nitrate concentrations at

some groundwater monitoring points, highlighting the importance of controlling agricultural non-point source pollution and protecting sensitive recharge areas [2]. Over-abstraction and seawater intrusion in coastal aquifers also require specific management.

Climate change further increases these vulnerabilities. IPCC assessments of the Mediterranean indicate that global warming of 1.5–2°C will substantially increase drought frequency, drought duration and water scarcity risks, while potentially increasing irrigation requirements [3]. The European Environment Agency also identifies growing risks of water stress, drought, flooding and saltwater intrusion in Southern Europe and densely populated areas [4]. For Antalya, these findings demonstrate that water supply planning based on historical averages is no longer sufficient.

2.2. Technical Assessment

Strengthening Antalya's water supply security should begin with protecting existing resources and managing demand before pursuing new sources. In sensitive drinking water source areas such as Kırkgöz, Duraliler, Boğaçayı, Doyran and Aksu, protection zones, wastewater infrastructure, agricultural chemical use and the control of unauthorised wells should be addressed together. Protection designations must translate into enforcement, permitting, sewer connections, agricultural advisory services and land-use decisions.

Long-term water budgets should be developed separately at basin and provincial scales. At basin scale, agricultural consumption, the surface water–groundwater balance and ecosystem requirements are decisive. At provincial and urban system scales, water losses, tourism-season demand peaks, urban population growth and energy costs become particularly important. Antalya should therefore adopt dynamic sub-basin water budgets and scenario-based supply security assessments rather than relying on a single estimate of water availability.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Update drinking water source protection plans, jointly assessing current land use, wastewater infrastructure, agricultural activities and well inventories. Prepare protection and inspection lists for critical sources; establish GIS-based records of unauthorised wells and abstraction. Expand nitrate, electrical conductivity, chloride and flow measurements at existing groundwater level and water quality monitoring points.	**Institutions:** ASAT, DSİ, Provincial Directorate of Agriculture and Forestry, Provincial Directorate of Environment, Urbanisation and Climate Change. **Indicators:** Number of monitored wells; number of unauthorised wells closed or licensed; trends in nitrate concentrations and electrical conductivity; number of source protection violations.
Medium term (3–5 years)	Update water budget tables at sub-basin scale. Establish early warning points for saltwater intrusion in coastal aquifers. Define allocation priorities for agriculture, drinking water, tourism and industry in advance of drought periods. Introduce pilot projects using treated wastewater and rainwater instead of	**Institutions:** DSİ, ASAT, Antalya Metropolitan Municipality, irrigation associations, agricultural associations and organised industrial zones. **Indicators:** Sub-basin water use index; volume of treated wastewater used; changes in chloride concentrations and electrical conductivity at coastal observation wells.

Long term (5+ years)	Prepare an Antalya Water Security Plan based on climate scenarios. Integrate safe groundwater reserves, ecosystem requirements, drought thresholds and sectoral allocation rules into a single decision support system. Link new source investments to the achievement of water loss reduction and reuse targets.	**Institutions:** Coordination by the Governor's Office, with ASAT, DSİ, ministries and universities. **Indicators:** Service continuity during drought; volume of water entering the system per capita; total abstraction-to-availability ratio; implementation of adaptation measures under climate scenarios.

3. Urban Water Management and Infrastructure Resilience

3.1. Current Situation

Urban water management in Antalya is a multidimensional challenge shaped by the expanding metropolitan service area, high summer population, tourism pressures, varied topography, ageing infrastructure and energy-intensive water supply. ASAT's 2025 water loss report records an annual system input volume of 396.44 million m^3, authorised consumption of 259.38 million m^3, water losses of 137.06 million m^3 and a water loss rate of 34.57%. The same report places non-revenue water at 45.93% [5]. These figures demonstrate that urban water supply security depends directly on improving metering, pressure management, failure management and leakage performance in the existing network, alongside investment in water sources.

For Antalya, reducing water losses is also an energy and carbon management priority. ASAT's 2025 report records annual electricity consumption of 327.22 GWh across drinking water abstraction, transmission and distribution systems [5]. Each cubic metre of water lost therefore represents wasted water resources and associated pumping, transmission, maintenance and greenhouse gas emission costs. Given Antalya Metropolitan Municipality's target of reducing greenhouse gas emissions by 40% by 2030, energy efficiency in water infrastructure is directly linked to climate policy [6].

Infrastructure resilience must also be assessed in relation to flooding and extreme precipitation. Urban development affecting stream channels and valleys, together with expanding impervious surfaces, reduces natural drainage capacity and exacerbates urban flooding and surface runoff. Protecting floodplains, developing green infrastructure and adapting infrastructure are prominent priorities in climate adaptation planning [6, 7].

3.2. Water Loss Management

Assessing the overall loss rate alone is insufficient for reducing water losses. Real and apparent losses must be monitored, reported and evaluated separately.

Real water losses are the component of water losses comprising water physically lost before reaching users. Their magnitude depends on pipe material and age, operating pressure, soil characteristics, environmental factors such as traffic loading, and the number and length of service connections. By location, they are classified as losses from transmission and distribution mains, losses from service connections, and losses from storage facilities.

As illustrated in Figure 1, real losses can be reduced to an economic level through pressure management, active leakage control, asset management, and improvements in the speed and quality of repairs. The remaining irreducible component is termed unavoidable annual real losses (UARL).

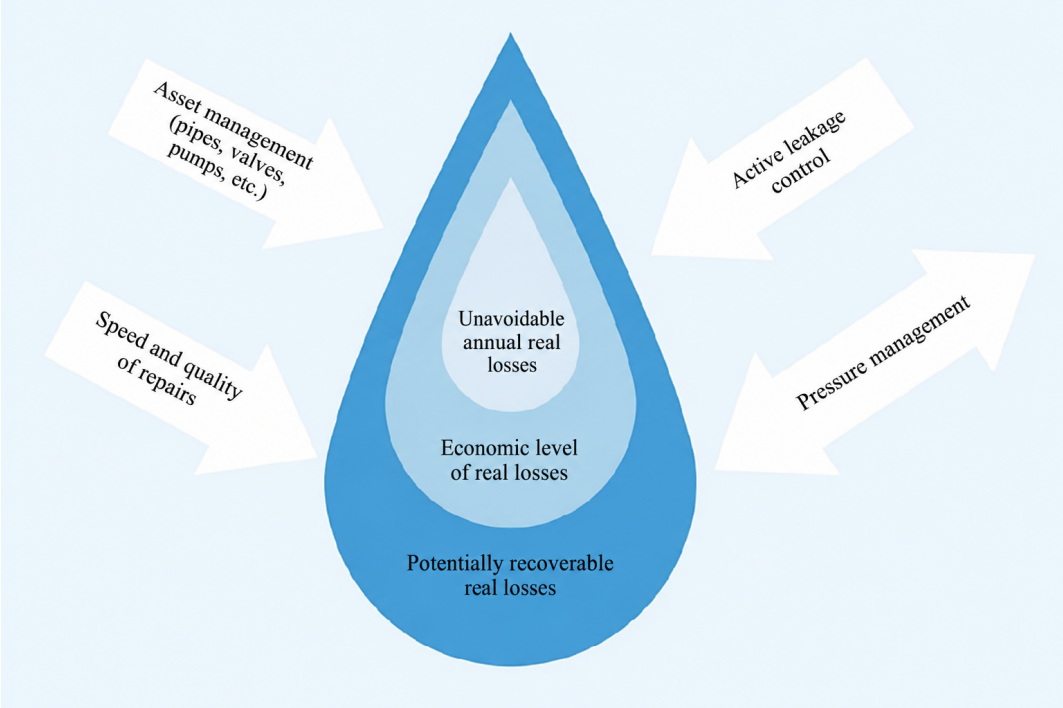


Figure 1. Intervention measures for real water loss management [8]

Apparent losses are the component of water losses arising when water reaches consumers but their consumption is not accurately measured and/or recorded, preventing water utilities or municipalities from recovering the corresponding revenue.

Unauthorised consumption, a component of apparent losses, results from illegal connections, meter tampering and unauthorised use of fire hydrants. Water consumed through these activities bypasses metering and is therefore not measured and/or recorded, contributing to apparent losses.

As illustrated in Figure 2, apparent losses can be reduced to an economic level by reducing unauthorised consumption, minimising meter inaccuracies, improving meter reading and data transfer, and enhancing data processing. The remaining irreducible component is termed unavoidable annual apparent losses.

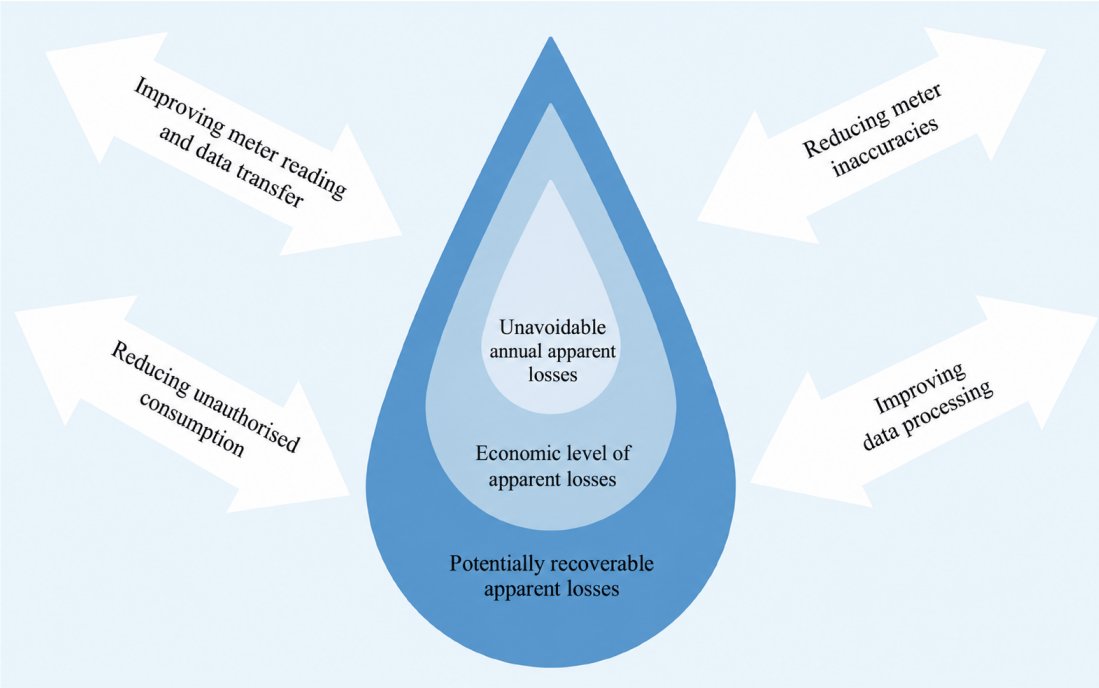


Figure 2. Intervention measures for apparent water loss management [8]

Reducing water losses in water supply systems requires an integrated and sustainable management approach.

3.3. Sponge Cities and Water-Sensitive Urban Design

For Antalya, the sponge city approach is an infrastructure component supporting flood mitigation, groundwater recharge, urban heat island mitigation and reduced pressure on drainage systems, beyond its landscape benefits. Rain gardens, bioswales, permeable paving, green roofs, rainwater storage tanks, small detention basins, stream corridor restoration and riparian buffers should be considered together. Stormwater management criteria linked to zoning decisions should be established, particularly for densely developed central districts, coastal tourism areas and new development zones.

Successful implementation requires conventional stormwater networks and blue–green infrastructure to be designed as complementary systems. Measurable criteria should be defined for new plot and area developments, including on-site retention or detention of the first 20–30 mm of rainfall, limits on impervious surface coverage, and mandatory permeable materials in parking areas and other paved spaces. The precise design requirements should be established through engineering assessments using Antalya's rainfall intensity–duration–frequency curves and local soil permeability.

3.4. Wastewater Reclamation

Wastewater reclamation is strategically important for Antalya for two reasons. First, it reduces pressure on freshwater resources. Second, it improves environmental quality by reducing coastal discharges and pollutant loads entering receiving waters. Treated wastewater can be used in parks and recreational areas, golf courses, firefighting, industrial processes and cooling, agricultural irrigation, and controlled groundwater recharge or surface water augmentation.

The fundamental principle is to move beyond a "single plant, single discharge" approach and identify potential users near treatment facilities. Reclaimed water supplies should be matched with demand for urban green space, median strip and park irrigation, tourism landscaping, golf courses, industrial processes

and suitable agricultural areas. This matching should jointly consider water quality classes, seasonal demand, storage requirements, conveyance costs, energy consumption and public health criteria.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Accelerate water balance assessments. Increase the number of flow and pressure measurement points at critical storage facilities and along trunk mains. Incorporate rainwater harvesting and on-site retention criteria into new urban projects as technical requirements, alongside the requirements established by building permits.	**Institutions:** ASAT, Antalya Metropolitan Municipality and district municipalities. **Indicators:** Failures per 100 km per year; water loss rate (%); leakage flow rate; energy consumption (kWh/m³); number of rainwater harvesting installations.
Medium term (3–5 years)	Prioritise pressure management and pipe replacement programmes using data on failures, pressure, pipe age, material and critical customers. Establish pilot reclaimed water networks for park and garden irrigation in central districts and tourism-intensive areas. Design pilot sponge city neighbourhoods in new development areas.	**Institutions:** ASAT, Antalya Metropolitan Municipality, İller Bankası, universities and tourism associations. **Indicators:** Length of network renewed (km); volume of reclaimed wastewater used (m³/year); proportion of green space irrigated with groundwater.
Long term (5+ years)	Integrate the province-wide digital twin/hydraulic model, SCADA, GIS, fault management and subscriber data within a single platform. Assess the capacity of stormwater, drinking water and wastewater infrastructure under climate scenarios. Establish treated wastewater as a mainstream alternative supply for tourism, urban landscaping and industry.	**Institutions:** ASAT, Antalya Metropolitan Municipality, ministries and financial institutions. **Indicators:** Portfolio of infrastructure investment adapted to climate scenarios; reclaimed water use rate; number of flood-related damage incidents; energy intensity; carbon-equivalent emissions reductions.

4. Agricultural Water Management

4.1. Current Situation

Agriculture is the principal driver of water use in the Antalya Basin, accounting for the largest share of sectoral water consumption [1]. Its scale places agricultural water management at the centre of Antalya's overall water security, alongside its importance for rural development.

Agricultural water use relies partly on surface water irrigation systems and partly on groundwater. Groundwater becomes the principal source particularly where surface water irrigation is unavailable, with important implications for declining groundwater levels and deteriorating water quality [1]. Elevated nitrate concentrations at some groundwater monitoring points demonstrate the need to consider the relationships between fertiliser application, drainage, greenhouse density and irrigation management [2].

Agriculture in Antalya faces two complementary climate risks. Rising temperatures and longer dry periods may increase irrigation requirements, while sudden, intense rainfall increases erosion, runoff, drainage problems and flood risks. IPCC assessments of the Mediterranean indicate that high temperatures and shorter growing periods will place crop yields under pressure in many areas and increase supplementary irrigation requirements for numerous crops [9].

Agricultural water management in Antalya should therefore extend beyond conversion to drip irrigation. Modern irrigation, cropping patterns, soil moisture monitoring, irrigation scheduling, drainage and salinity control, fertiliser optimisation, reclaimed water use and farmer training should be implemented together.

4.2. Modern Irrigation Systems and Digital Agriculture

The transition to modern irrigation in Antalya should address water rights, energy costs, maintenance capacity and irrigation scheduling alongside equipment investment. Even where drip or sprinkler systems are installed, operations unsupported by soil moisture measurements, crop water requirements and climate data may fail to deliver the expected savings. Digital agriculture should therefore begin with simple, reliable farm-level irrigation schedules, followed by decision support incorporating sensors, meteorological data and remote monitoring.

Water savings must be carefully balanced against potential yield losses. Applying uniform irrigation reductions to all crops during water shortages is inappropriate. Cropping patterns, economic value, water consumption, employment impacts and food security should be assessed jointly at sub-basin scale. This approach should also underpin dynamic water allocation protocols.

4.3. Cropping Patterns and Drought-Adapted Agriculture

Cropping pattern planning in Antalya is a social and economic issue as well as a technical one. Recommendations to replace water-intensive crops with strategically important, less water-demanding alternatives are unlikely to be practicable without considering farm incomes and market structures. Changes should therefore be designed together with agricultural support policies, purchase guarantees, cooperative development, irrigation tariffs and advisory services.

Water efficiency measures differ between greenhouse cultivation, open-field production and fruit growing. In greenhouses, priorities may include recirculating nutrient solution systems, drainage water monitoring, salinity control and reuse following disinfection. In open-field production, rainwater harvesting, increasing soil organic matter, mulching, appropriate tillage, pressurised irrigation, and drainage and salinity management are likely to be more influential.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Update the sub-basin database covering irrigated areas, cropping patterns, water sources, well inventories and irrigation methods. Strengthen inspections of unauthorised wells and nitrate–salinity monitoring in critical groundwater areas. Provide practical farmer training on irrigation scheduling, soil moisture, fertiliser application and drainage.	**Institutions:** DSİ, Provincial Directorate of Agriculture and Forestry, irrigation associations, chambers of agriculture and universities. **Indicators:** Up-to-date well inventory; number of farmers trained; monitored nitrate and electrical conductivity trends; proportion of irrigated land under pressurised irrigation.

Medium term (3–5 years)	Establish pilot advisory services to improve the operation of drip and other pressurised irrigation systems. Develop cropping pattern scenarios based on water budgets and link them to agricultural support mechanisms. Develop pilot projects for reclaimed wastewater irrigation, addressing water quality, storage, conveyance and farmer	**Institutions:** Ministry of Agriculture and Forestry, DSİ, ASAT, municipalities and cooperatives. **Indicators:** Water consumption (m^3/da); water productivity; pilot reclaimed water irrigation area; groundwater level trends.
Long term (5+ years)	Establish a dynamic sub-basin water allocation model and implement drought-period prioritisation rules by crop, region and water source. Integrate agricultural water efficiency, energy efficiency and fertiliser management. Update groundwater abstraction limits in coastal aquifers and plains according to climate scenarios.	**Institutions:** Governor's Office, ministries, DSİ, ASAT, universities and producer organisations. **Indicators:** Abstraction-to-yield ratio; agricultural water productivity; nitrate reduction trends; area under priority crops during drought.

5. Water Management in Tourism and Industry

5.1. Current Situation

Tourism-related water management in Antalya should be approached as a water system challenge characterised by high seasonal demand peaks rather than constant year-round demand. According to Ministry of Culture and Tourism data for 2025, Antalya received more than 16.3 million international visitors between January and October [10]. This scale makes accommodation facilities important not only for operational water efficiency but also for peak urban demand, wastewater infrastructure, landscape irrigation and energy consumption.

An academic study of accommodation facilities in Antalya found that direct water consumption across 20 establishments ranged from 103 to 1,209 litres per guest-night [11]. This wide variation demonstrates the strong influence of facility category, occupancy, landscaped area, laundry practices, kitchen operations, in-room fixtures, pools and irrigation management. Detailed measurements at one five-star establishment disaggregated direct consumption by operational area, demonstrating the need to manage irrigation, guest rooms, kitchens, laundries, communal areas and pools separately [11].

ASAT's 2025 customer consumption data report metered consumption of 44.62 million m^3/year for hotel and guesthouse accounts [5]. This figure demonstrates that tourism water efficiency programmes are demand management instruments with direct implications for Antalya's drinking water and wastewater systems, alongside their environmental benefits.

Industrial water use in Antalya OIZ and other industrial facilities includes process, cooling, cleaning and landscaping requirements that vary by sector. The Provincial Environmental Status Report provides water use data for Antalya OIZ but indicates gaps in province-wide information on the sources supplying industrial water [2]. This highlights the need for inventories and monitoring to support industrial water efficiency.

5.2. Hotel Water Efficiency, Greywater and Water Reuse

Water efficiency in tourism facilities extends beyond replacing in-room fixtures with low-flow alternatives. Effective savings require submetering, departmental water budgets, landscape irrigation optimisation, laundry load management, reduced pool filter backwash water use, efficient kitchen equipment and staff training. Each facility should monitor water consumption per guest-night alongside occupancy, landscaped area and service concept.

Greywater use and landscape irrigation with treated wastewater are particularly valuable in tourism areas. However, implementation must address public health, odour, storage, conveyance, water quality class, maintenance and user acceptance. Centralised reclaimed water distribution networks may provide safer and more readily monitored solutions than individual greywater systems in tourism areas. Conversely, on-site greywater systems may be suitable for large, isolated facilities with sufficient technical operating capacity.

Closed-loop systems should be prioritised for assessment in industry and large tourism facilities. Increasing cooling water cycles of concentration, recovering backwash and filter-cleaning water, automating kitchen and laundry equipment, using condensate and storing rainwater can reduce peak demand on water resources.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Launch a water efficiency monitoring programme for tourism facilities, linking water consumption per guest-night to submetered consumption, landscaped area and occupancy. Require submetering and landscape irrigation audits at large facilities. Prepare water use inventories for OIZs and major industrial users.	**Institutions:** ASAT, Provincial Directorate of Culture and Tourism, tourism associations, OIZs and municipalities. **Indicators:** Litres per guest-night; submetering coverage; total hotel and guesthouse consumption; industrial water intensity expressed as m^3 per unit of output or per unit of turnover.
Medium term (3–5 years)	Establish pilot reclaimed water distribution networks for landscape irrigation in tourism areas. Link water efficiency audits in large hotels to incentive and certification schemes. Prepare sectoral guidance on closed-loop cooling, process water recovery and rainwater	**Institutions:** ASAT, tourism businesses, ministries, OIZs and universities. **Indicators:** Volume of reused water (m^3/year); number of certified facilities.
Long term (5+ years)	Prepare an alternative water supply master plan for tourism and industrial areas. Integrate treated wastewater and rainwater use, peak demand reduction and water–environment indicators into permitting for major new tourism investments. Through industrial symbiosis, enable one business's effluent to serve as an input to another process meeting the required water quality specifications.	**Institutions:** Antalya Metropolitan Municipality, ASAT, ministries and sectoral associations. **Indicators:** Water consumption per person or guest-night; alternative water share; peak daily demand; industrial water recovery rate.

6. Governance, Institutional Arrangements, Financing and Participation

6.1. Current Situation

Water management in Antalya, as elsewhere in Türkiye, involves multiple institutions. DSİ, ASAT, Antalya Metropolitan Municipality, district municipalities, the Provincial Directorate of Agriculture and Forestry, the Provincial Directorate of Environment, Urbanisation and Climate Change, irrigation associations, tourism and industry organisations, universities and civil society hold responsibilities for different parts of the same water cycle. When effectively coordinated, this institutional diversity provides substantial capacity. Weak coordination, however, creates risks of inconsistent data, duplicated investment and delayed intervention.

Financing is often perceived as the weakest component of water management, yet it is among the most decisive. Water loss reduction, pipe renewal, SCADA, wastewater reclamation, stormwater infrastructure, green infrastructure and irrigation modernisation require different financing models. Investment priorities in Antalya should therefore be determined by water and energy savings, emissions reductions, avoided flood damage, ecosystem benefits and public acceptance, alongside construction costs.

Participation mechanisms are essential for translating technically sound measures into practice. Farmers, hotel operators, industrial users, residents, professional chambers and universities should be involved early in decision-making. Measures introduced during water shortages become harder to implement if they have not been communicated beforehand. Drought communication and demand management should therefore be core instruments of water governance in Antalya.

6.2. Water Governance Model

The proposed governance model has three tiers. The first is a strategic board coordinating basin-level water budgets, drought management, ecosystem requirements and allocation decisions. The second is a technical implementation structure through which ASAT and municipalities deliver drinking water, wastewater, stormwater, green infrastructure and urban planning measures. The third comprises sectoral participation platforms supporting demand management and behavioural change in agriculture, tourism, industry and neighbourhoods.

A minimum common set of indicators is essential, even where institutions cannot share all data in a single format. Monthly system input volumes, authorised consumption, water losses, groundwater levels, water quality, treated wastewater volumes, irrigation volumes, tourism consumption, energy consumption and drought indices should be monitored through a shared management dashboard.

6.3. Policy and Regulatory Alignment

Policy and regulatory alignment should be addressed jointly at national and local levels. The National Climate Change Adaptation Strategy and Action Plan seeks to incorporate climate risks into water resource management, strengthen adaptive capacity and integrate adaptation into sectoral plans [7]. Locally, Antalya Metropolitan Municipality’s mitigation and adaptation work supports flood management, green infrastructure and infrastructure adaptation in urban water management [6].

The central regulatory challenge is integrating water-sensitive urban design and alternative water use into zoning, permitting, environmental approval and infrastructure acceptance procedures. Rainwater harvesting, greywater use, reclaimed water irrigation, mandatory permeable surfaces and water efficiency audits for major users should be governed by clear technical specifications.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Establish an Antalya Water Management Coordination Platform or strengthen the existing board structures at the technical level. Prepare an interinstitutional protocol establishing minimum data-sharing requirements. Define common indicators for water losses, drought, agriculture, tourism and reuse. Publish an annual Antalya Water Status Bulletin for the public.	**Institutions:** Governor's Office, ASAT, DSİ, Antalya Metropolitan Municipality, provincial directorates and universities. **Indicators:** Number of meetings; number of datasets shared; number of bulletins published; number of participating institutions.
Medium term (3–5 years)	Select water investments through multicriteria prioritisation. Prepare local technical guidance on rainwater harvesting, treated wastewater use and water efficiency audits. Develop sector-specific water efficiency protocols for agriculture, tourism and industry.	**Institutions:** Antalya Metropolitan Municipality, ASAT, ministries, professional chambers and sectoral associations. **Indicators:** Number of guides; number of protocols; number of projects financed; water saved per unit of investment (m^3).
Long term (5+ years)	Formally adopt and implement the Antalya Climate-Resilient Water Management Master Plan with legal and institutional ownership. Align water tariffs, incentives, funds and performance targets to support demand management. Announce in advance the phased measures and water allocation protocol to be applied during drought.	**Institutions:** Governor's Office, ministries, ASAT, DSİ and Antalya Metropolitan Municipality. **Indicators:** Master plan implementation rate; compliance with water allocations; drought response time; sector-specific savings.

7. Decision Support Mechanism

A substantial volume of water management data is generated in Antalya. However, using these data strategically and comprehensively to support decision-making is particularly important. The primary function of a decision support mechanism is to translate data produced by different institutions and sectors into timely, actionable management decisions, alongside monitoring and archiving. For example, drought warnings based solely on meteorological drought indices may not adequately capture the implications for drinking and domestic water supply or agricultural production.

Assessing precipitation deficits, river flows, groundwater levels, reservoir and storage tank levels, consumption trends, tourism occupancy rates, irrigation demand and reclaimed water potential together can produce a more realistic warning system that reflects local conditions and enables early intervention. Data integration in Antalya should therefore adopt a multilayered structure. The first layer should comprise field measurements, including flow, pressure, water levels, water quality, energy consumption, precipitation, soil moisture and treatment plant effluent quality.

The second layer should comprise GIS-based spatial data infrastructure, linking sub-basin boundaries, pipelines, storage facilities, treatment plants, wells, irrigated areas, tourism facilities and sensitive ecosystems within a shared database. The third layer should contain analytical tools, including water budgets, hydraulic modelling, drought indices, demand forecasts and risk maps. The fourth should be a decision dashboard enabling warning generation, prioritisation and performance monitoring.

Monitoring networks should prioritise risk-based measurement points that directly address management needs. Salinity should be monitored in coastal aquifers; nitrate and electrical conductivity in intensive agricultural areas; pressure and flow in high-pressure zones; peak consumption in tourism areas; and rainfall and water levels in flood-prone locations. This directly links data investment to operational management challenges.

Sectoral water allocation is another important component. Antalya should apply different allocation rules under normal-year and drought-year conditions. In normal years, the principal objectives should be improving efficiency, protecting source water quality and meeting sectoral demand sustainably. During drought years, phased measures based on predefined thresholds should govern drinking and domestic water supply, ecosystem requirements, critical agricultural production, tourism and industrial uses.

Without scientifically defined thresholds, drought management becomes crisis management rather than planned risk management. Cropping pattern optimisation is a critical element of agricultural allocation, but it should extend beyond selecting the least water-intensive crops. Decisions should jointly consider water consumption, income, employment, export potential, food security, ecosystem impacts and farmer acceptance. In tourism, consumption per guest-night and facility water efficiency classifications should become practical indicators for demand management, incentives and sustainable tourism initiatives.

The Antalya Water Management Dashboard should have two levels: a restricted management interface for public institutions and authorised technical teams, and a clear, accessible public information interface. The technical interface should jointly monitor sub-basin water budgets, ASAT system input volumes, consumption and losses, failure concentrations, groundwater level and quality trends, reclaimed water potential, seasonal tourism demand and agricultural irrigation requirements.

The public interface should communicate current water conditions, conservation appeals, drought levels and adopted measures clearly, without excessive technical detail. The early warning system should explicitly define which institution must initiate which action when a threshold is exceeded. For example, groundwater levels falling below critical thresholds should trigger coordinated inspections of unauthorised wells, irrigation restrictions, activation of alternative supplies and public information campaigns.

The decision support mechanism is therefore a strategic governance instrument that strengthens interinstitutional coordination, clarifies responsibilities and establishes data-driven water management, alongside its technical monitoring and analytical functions.

Timeframe	Recommendations	Responsible Institutions and Monitoring Indicators
Short term (0–2 years)	Inventory existing data sources and prepare a common data dictionary covering ASAT, DSİ, MGM, agriculture, tourism and wastewater data. Prioritise flow, pressure, water level and water quality measurements in critical areas to close monitoring gaps. Pilot a basic Antalya Water Status Dashboard.	**Institutions:** ASAT, DSİ, MGM, Provincial Directorate of Agriculture and Forestry, Antalya Metropolitan Municipality and universities. **Indicators:** Number of integrated datasets; monitoring gaps; dashboard update frequency.

Medium term (3–5 years)	Monitor groundwater levels, water quality and drought indices on a shared platform. Develop demand forecasting modules for agriculture and tourism. Prepare sectoral action protocols linked to drought thresholds.	**Institutions:** ASAT, DSİ, universities and sectoral associations. **Indicators:** Model calibration performance; forecast error; time taken to implement measures when drought thresholds are reached; data-sharing protocol.
Long term (5+ years)	Jointly analyse sub-basin water budgets, urban water networks, wastewater reclamation, stormwater, agriculture and tourism demand under climate scenarios. Link investment programmes to decision support outputs.	**Institutions:** Governor's Office, ASAT, DSİ, ministries and universities. **Indicators:** Digital twin coverage; number of scenario analyses; use of models in investment decisions; early warning accuracy.

8. Conclusion

The priority for water management in Antalya is to anticipate how existing pressures will intensify through climate change, population growth, tourism and agricultural water demand, rather than waiting for future supply shortages. Groundwater dependence, salinisation risks in coastal aquifers, localised water quality pressures, high water losses, tourism-season consumption peaks and irrigation requirements are the principal factors shaping Antalya's water security. Water management should therefore adopt an integrated approach encompassing the basin, urban systems, agriculture, tourism and ecosystems, extending beyond individual infrastructure investments.

Antalya's conventional supply-oriented approach must be complemented by robust demand and water loss management. Reducing losses, strengthening pressure and failure management, reusing treated wastewater, retaining rainwater within urban areas, managing irrigation through data, lowering water consumption per unit of activity in tourism and industry, and effectively enforcing source protection measures are critical to a climate-resilient water future. Although each represents a distinct project area, success ultimately depends on bringing them together through shared data, targets and monitoring systems.

The most practical starting point is to establish a common indicator set, a data-sharing protocol and a decision support mechanism among existing institutions. This transition offers the most reliable pathway to protecting water resources and preparing Antalya's agriculture, tourism, industry and quality of life for the future.

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ID	Group 4 / Working Group on Sustainable Agriculture, Sustainable Ecosystems and Sustainable Tourism	Meeting I Online 30 April, 14:30	Meeting II Online 14 May, 14:30	Meeting III In person at ANSİAD 4 June, 14:30	Meeting IV In person at ANSİAD 25 June, 14:30
1	**Zafer ALKAYA** – Member of the Board of Directors, AKTOB	No			
2	**Assoc. Prof. Dr. Güray DOĞAN** – Faculty Member, Department of Environmental Engineering, Faculty of Engineering, Akdeniz University; Member of the Board of Directors, Chamber of Environmental Engineers	Yes	Yes	Yes	Yes
3	**Gökçen ATMACA** – Chair of the Board of Directors, AGİDER	No		No	
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12	**Ergün DURAN** – Chair, ANSİAD Agriculture and Food Working Committee	Yes	Yes	Yes	
13	**Aysel DAL CENGİZ** – Member, ANSİAD Agriculture and Food Working Committee	Yes	Yes	Yes	Yes
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15	**Dr. Elçin Kökdemir Ünşar** – Member, TMMOB Chamber of Environmental Engineers				

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12	**Ergün DURAN** – Chair, ANSİAD Agriculture and Food Working Committee	1.1, 1.3, 1.6, 1.7, 1.8, 1.10, 1.11 and 1.12
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CHAPTER

04

ANTALYA
2050

ANTALYA 2050 / COP31

SUSTAINABLE AGRICULTURE, SOIL AND ECOSYSTEM MANAGEMENT

SOIL · BIODIVERSITY · CLIMATE-RESILIENT PRODUCTION

- Sustainable production
- Soil and water balance
- Nature-based solutions

A Strategy for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

SUSTAINABLE AGRICULTURE AND ECOSYSTEMS

Historical Development of Agriculture in Antalya

Antalya is one of Anatolia's most important agricultural production centres, with a history spanning thousands of years. Its fertile coastal plains, rich alluvial soils, favourable climate and water resources have sustained continuous agricultural production throughout its history.

During antiquity, under the civilisations of Pamphylia, Lycia and Pisidia, cereals, grapes, olives, figs and various fruits were cultivated on the coastal plains, particularly the Antalya Plain. The region also became an important trading centre. Agricultural products were transported through port cities to other parts of the Mediterranean, and agriculture became a principal regional economic activity.

Agriculture retained its importance during the Seljuk and Ottoman periods, with expanding citrus, olive, grape, sesame, cotton and cereal production. Influenced by Yörük culture, crop production and livestock husbandry were practised together for many years, while seasonal transhumance in the Taurus Mountains became an important component of rural life.

Following the proclamation of the Republic, mechanisation, irrigation investment and cooperative development marked a new phase in Antalya's agriculture. Modern greenhouse cultivation, introduced particularly from the 1960s onwards, brought substantial transformation. The spread of plastic-covered greenhouses enabled year-round production and accelerated the economic development of vegetable growing.

After the 1980s, export-oriented production strengthened, and protected vegetable cultivation expanded rapidly, particularly for tomatoes, peppers, cucumbers and aubergines. Citrus production also increased, while cut flowers, seedlings, nursery plants and ornamental plants developed as commercial sectors. From the 2000s onwards, modern greenhouse technologies, drip irrigation, biological control and certified production became more widespread, establishing Antalya as Türkiye's centre for protected cultivation.

Today, Antalya is a leading province in fresh fruit and vegetables, protected cultivation, citrus, avocados, mangoes, bananas, ornamental plants, seedlings, nursery plants and seed production. Its developed logistics infrastructure and export capacity support agricultural exports to Europe, Russia, the Middle East and numerous other markets.

Agriculture in Antalya Today

Despite its substantial production capacity and technological development, Antalya's agriculture faces major challenges, including climate change, drought, declining water resources, conversion of agricultural land to non-agricultural uses, rising production costs and an ageing rural population. Protecting natural resources has become as important as production itself in ensuring agricultural sustainability.

Agricultural Development and Antalya's 2050 Vision

With its diverse climate, fertile plains, developed greenhouse infrastructure and export-oriented production, Antalya is a driving force in Turkish agriculture. As the national leader in protected cultivation, it is an important production centre for fresh produce, ornamental plants, seedlings, nursery plants and seeds across both Türkiye and the Mediterranean Basin. It has long ranked among Türkiye's leading provinces by agricultural production value and has considerable experience in modern greenhouse cultivation, contract farming and integration into international markets.

However, the next quarter-century will involve more than increasing production. Climate change, declining water resources, rising temperatures, drought, extreme weather, land fragmentation, urban development

pressure and rural ageing will directly shape agriculture's future. The central challenge is increasingly to sustain production while conserving natural resources. Antalya's 2050 vision studies likewise identify water management, climate resilience and green transition as critical priorities.

Towards 2050, Antalya's principal agricultural objective should be a highly productive model that conserves natural resources, uses digital technologies, adapts to climate change and strengthens international competitiveness. This transformation requires both technological adoption and an integrated rural development approach centred on soil, water and biodiversity conservation.

The principal elements of Antalya's 2050 agricultural vision can be summarised as follows:

- Expanding water-efficient pressurised irrigation and developing rainwater harvesting;
- Reducing groundwater use and strengthening basin-based water management;
- Expanding organic matter management, erosion control and precision agriculture to prioritise soil health;
- Making digital agriculture, AI-enabled decision systems, sensors, remote sensing and agricultural data management integral to production;
- Developing low-carbon greenhouses powered by renewable energy;
- Increasing research and development investment in seeds, seedlings, nursery plants, biological control and biotechnology;
- Processing agricultural commodities into high-value products;
- Supporting young farmers, women entrepreneurs and agricultural technology ventures;
- Expanding agritourism, local product branding and rural development models integrating agriculture and tourism; and
- Protecting agricultural land and reducing unplanned development pressure on fertile plains.

Conclusion

With more than two millennia of accumulated agricultural experience, Antalya has remained an important Mediterranean production centre. Future success, however, will depend on soil conservation, effective water management, technological transformation and climate adaptation alongside production volumes.

The agricultural ecosystem envisaged for Antalya in 2050 should conserve natural resources, embrace digitalisation, generate high added value and support low-carbon, sustainable development. This transformation requires a shared vision among public institutions, universities, research organisations, producer organisations and the private sector.

1. Agricultural Land Protection and Sustainable Land Management

1. Scope and Current Situation

Agricultural land is strategically important for food security, natural resource conservation, rural development and a sustainable economy. Rapid urbanisation, population growth, industrialisation, tourism investment and infrastructure projects are nevertheless placing increasing pressure on fertile land.

Across Türkiye, conversion to non-agricultural uses is becoming more common, particularly around metropolitan areas and along the coast. In Antalya, tourism development, second homes, transport projects

and unplanned land-use changes can substantially reduce irrigable plains, greenhouse areas and highly productive soils.

Inheritance-related fragmentation also increases the prevalence of small, economically unviable farms, limiting productivity and the applicability of modern techniques. Declining water resources and drought risks associated with climate change make sustainable land management increasingly critical.

Agricultural land protection, land-use planning and sustainable production are priority policy areas for FAO, IPCC, OECD and relevant Turkish institutions.

2. Identification of Problems

- Increasing development pressure on fertile land;
- Rezoning agricultural land for construction and irreversible land loss;
- Unplanned land-use changes and conversion to non-agricultural uses;
- Inheritance-related fragmentation and loss of economic scale;
- Increasing coastal tourism and second-home pressures;
- Pressure from industrial, energy and transport investment;
- Insufficient consideration of climate change in production planning;
- Small, fragmented farms constraining modern agriculture;
- Inadequate inspection and enforcement;
- Insufficient digital land monitoring and data infrastructure;
- Incomplete implementation of integrated long-term agricultural policies; and
- Insufficient integration of soil and water resources into planning.

3. Proposed Solutions

- Place prime agricultural land and special crop land under strict protection.
- Base non-agricultural use permits on technical criteria and scientific assessments.
- Expand regional and basin-based production planning.
- Accelerate and support land consolidation.
- Strengthen legal and structural measures limiting inheritance-related fragmentation.
- Encourage cooperatives and joint production models.
- Monitor agricultural areas digitally through GIS.
- Integrate climate projections into land-use plans.
- Redesign agricultural infrastructure for climate adaptation.
- Plan strategic crops according to regional capacity.
- Develop effective inspection and enforcement mechanisms.
- Train farmers in sustainable agriculture and modern production techniques.

4. Conclusion

Protecting agricultural land is essential to production continuity, food security, rural development, ecosystem balance and economic sustainability.

Regions such as Antalya, where agriculture, tourism and urbanisation exert simultaneous pressures, require strategic planning. Protecting fertile land, preventing fragmentation, ensuring planned use and developing climate-adapted production are fundamental to long-term sustainability.

These policies will directly affect current capacity, future generations' food security and natural resource sustainability.

5. References

- 5403 Sayılı Toprak Koruma ve Arazi Kullanımı Kanunu
- T.C. Tarım ve Orman Bakanlığı, Tarım Arazilerinin Korunması ve Arazi Yönetimi Politikaları
- FAO, Sustainable Land Management Reports
- IPCC, Climate Change and Land Report
- OECD, Agricultural Policy Monitoring and Evaluation
- Ziraat Mühendisleri Odası yayınları
- ANSİAD raporları
- Antalya İl Tarım ve Orman Müdürlüğü, bölgesel tarımsal üretim ve arazi kullanım verileri

The following texts have been prepared in academic and technical language suitable for an Antalya Metropolitan Municipality vision report or similar strategic reports produced by organisations such as ANSİAD. Numerical data and assessments of current conditions have been developed with reference to Antalya's coastal and wetland systems, tourism pressures and environmental indicators.

2. Sustainable Management of Coastal Areas and Wetlands

1. Scope and Current Situation

Wetlands are critical ecosystems for biodiversity, flood control, carbon storage, groundwater recharge and sustainable tourism. Antalya hosts important systems including the Aksu Delta, Boğazkent Bird Sanctuary, Köprüçay Delta, Manavgat River wetlands and Finike–Demre coastal wetlands.

Four important wetlands in Antalya have national or local protection status. Antalya is Türkiye's leading tourism centre.

Intensive tourism along Belek, Kundu, Lara and Manavgat places substantial pressure on wetlands. Climate-related drought, groundwater abstraction and land-use change have reduced water levels in some areas. Habitat losses have been reported in parts of Yamansaz, Boğazkent and the Aksu Delta. Wetlands also offer opportunities to diversify tourism through birdwatching, nature tourism and ecotourism.

Lagoons and deltas are sensitive, highly productive transition zones between terrestrial and marine ecosystems. The Aksu, Köprüçay and Manavgat deltas and Boğazkent coastal lagoons provide habitats for migratory birds, fish and endangered species. Lagoon systems along Belek and Serik are also associated with loggerhead turtle (*Caretta caretta*) nesting areas. Over the past three decades, tourism, golf courses, transport infrastructure and unplanned urbanisation have substantially altered these systems. Sea-level rise and erosion pose additional threats.

Summer populations increase severalfold in many districts, placing pressure on marine ecosystems. Despite substantial domestic wastewater treatment investment, marinas, cruise tourism, shipping, recreational boats, stormwater discharges and microplastics remain important pollution sources. Antalya Metropolitan Municipality's Electronic Ship Monitoring System led to administrative sanctions against 17 vessels identified as polluting the sea during the first half of 2025, demonstrating the continuing significance of vessel-source pollution.

Coastal dunes, reed beds, *Posidonia oceanica* meadows, cliff ecosystems and lagoons are important habitats. They support erosion prevention, carbon storage, water quality and biodiversity. Tourism facilities, waterfront development, coastal structures and intensive recreation have caused fragmentation and habitat loss, particularly along Lara, Belek and Kemer. Sea-level rise and extreme weather further reduce resilience.

2. Identification of Problems

Wetland Ecosystem Conservation

- Wetland contraction from tourism and second-home development;
- Hydrological disruption from groundwater abstraction;
- Habitat loss through agricultural drainage;
- Illegal filling and land reclamation;
- Inadequate implementation of management plans;
- Increasing drought and evaporation;
- Biodiversity loss and declining migratory bird populations; and
- Underutilised ecotourism potential.

Lagoon and Delta Conservation

- Development pressure;
- Disrupted sediment transport from reclamation and protection structures;
- Increased water consumption by golf courses and landscaping;
- Absence of sea-level rise adaptation plans;
- Ecological corridor disruption through fragmentation; and
- Unauthorised uses and recreational pressure.

Marine Pollution Prevention

- Wastewater discharges from ships and yachts;
- Oil and chemical pollution from marinas and ports;
- Increasing plastic and microplastic loads;
- High seasonal wastewater volumes;
- Stream-borne pollutants;
- Unmanaged coastal recreation; and
- Gaps in continuous seawater quality monitoring.

Coastal Habitat Restoration

- Dune destruction;
- Seagrass decline;
- Habitat loss from waterfront development;
- Increasing erosion;
- Tourism-related fragmentation;
- Invasive species spread; and
- Limited restoration projects.

3. Proposed Solutions

Wetland Ecosystem Conservation

- Prepare an Antalya Wetland Management Master Plan.
- Protect groundwater and surface water sustaining wetlands.
- Establish buffer zones and restrict construction.
- Require wetland carrying capacity assessments for tourism investment.
- Restore habitats in Boğazkent and the Aksu Delta.
- Develop birdwatching towers, nature education centres and ecotourism routes.
- Establish remote sensing and GIS monitoring.
- Create governance arrangements involving local authorities, tourism and civil society.

Lagoon and Delta Conservation

- Prepare dedicated protection and restoration programmes for the Aksu and Köprüçay deltas.
- Review development boundaries.
- Encourage nature-based coastal protection.
- Restore dunes and reed beds.
- Prepare sea-level rise adaptation plans.
- Define visitor carrying capacity in sensitive areas.
- Introduce ecological certification for tourism businesses.

Marine Pollution Prevention

- Expand electronic vessel monitoring.
- Extend zero-waste and Blue Port practices in marinas.
- Establish microplastic monitoring.
- Encourage advanced treatment and reclamation in coastal hotels.
- Separate stormwater and sewer systems.
- Share seawater quality data publicly in real time.

- Develop local measures reducing tourism-related plastic use.

Coastal Habitat Restoration

- Prepare an Antalya Coastal Habitat Inventory.
- Establish seagrass protection zones.
- Restore degraded dunes.
- Develop nature-based coastal protection.
- Monitor habitat carbon sink capacity.
- Require ecological compensation for tourism-related habitat loss.
- Develop blue carbon projects and access international funding.

4. Conclusion

Wetland conservation is strategically important for biodiversity, water security, adaptation and sustainable tourism. Balancing protection and use is essential to preserving Antalya's natural capital for future generations.

Lagoons and deltas form the ecological backbone of coastal systems. Their protection requires long-term planning for biodiversity, coastal safety and tourism.

Clean seas underpin Antalya's tourism economy. Pollution prevention is critical to destination competitiveness and economic sustainability.

Restoration will strengthen adaptation and protect natural tourism assets. Nature-based solutions and ecosystem restoration should be central to sustainable coastal management.

5. References

1. Tarım ve Orman Bakanlığı, Sulak Alanlar Yönetimi ve Korunan Alan İstatistikleri, 2025.
2. Kesici, E. (2025). Antalya Sulak Alanlarının Durumu ve Tehditleri.
3. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Korunan Alanlar Göstergeleri, 2025.
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6. Ramsar ve Akdeniz Kıyı Sulak Alanları Koruma Yaklaşımları. (Navigatormap)
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8. Akdeniz Havzasında Deniz Kirliliği ve Turizm Baskıları Literatürü.
9. UNEP Mediterranean Action Plan Raporları.
10. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı Korunan Alanlar Verileri, 2025. (Çevre Bakanlığı)
11. Akdeniz Kıyı Ekosistemleri ve Mavi Karbon Çalışmaları.
12. UNEP-MAP Akdeniz Kıyı Alanları Yönetimi Rehberleri.

3. Environmentally Sound Input Management in Agricultural Production

1. Scope and Current Situation

Population growth, changing consumption and food security requirements necessitate greater agricultural productivity. However, chemical fertilisers, pesticides and intensive irrigation can degrade soils, pollute groundwater and surface water, reduce biodiversity and increase greenhouse gas emissions [1], [2].

Antalya, Türkiye's protected cultivation centre, reportedly contains more than 67,000 hectares of greenhouses. It produces approximately one-quarter of the country's fresh vegetables and is a leading producer of tomatoes, peppers, cucumbers, aubergines, citrus, avocados and tropical fruits [3]. Intensive production can raise fertiliser and pesticide use above national averages, increasing nitrate accumulation and agricultural pollution risks, particularly in Aksu, Serik, Kumluca, Finike, Demre and Manavgat [4].

Annual chemical fertiliser consumption in Türkiye has recently been approximately 6–7 million tonnes. Per-hectare use in intensive protected cultivation can be several times that of open-field production [1]. Pesticide use in the Mediterranean Region also exceeds national averages, making residue management increasingly important for exports [5].

Agriculture and tourism are directly linked. Nitrate, phosphorus and pesticide loads affect groundwater, rivers and coastal ecosystems, threatening clean water, landscapes and environmental quality. Environmentally sound input management is therefore strategically important for tourism competitiveness as well as agricultural sustainability.

Organic agriculture, good agricultural practices, biological control, precision agriculture and circularity are gaining importance under the European Green Deal, Farm to Fork Strategy, carbon-neutral production and sustainable tourism policies [2], [6]. Expanding biological control and certified production in Antalya are positive developments, but wider implementation remains necessary.

2. Identification of Problems

- Fertiliser use frequently lacks soil and leaf analysis.
- Excess nitrogen can accumulate as groundwater nitrate.
- Phosphorus increases eutrophication risks.
- Pesticides may be applied without reference to economic injury thresholds.
- Residues can lead to export consignment rejection.
- Beneficial insect populations and ecological balance are declining.
- Soil organic matter is often below sustainable levels.
- Agricultural carbon footprints are insufficiently monitored.
- Farmer knowledge of biological and integrated control may be inadequate.
- Certification costs burden producers.
- Data-driven precision agriculture is insufficiently adopted.
- Integrated management addressing agriculture–tourism interactions is underdeveloped.

3. Proposed Solutions

Optimising Fertiliser Use

- Base programmes on soil and leaf analysis.
- Expand precision technologies and sensors.
- Encourage controlled-release and organomineral fertilisers.
- Support drip irrigation and fertigation.
- Establish nutrient budgets and digital fertiliser tracking.
- Develop basin-scale nitrate monitoring.

Reducing Pesticide Use

- Expand integrated pest management (IPM).
- Base applications on economic injury thresholds.
- Gradually reduce active substances associated with high residue risks.
- Establish digital pesticide records.
- Monitor residues regularly.
- Introduce protection programmes where agriculture and tourism interact intensively.

Biological Control

- Increase support for beneficial insects, predators and parasitoids.
- Expand biotechnical control in greenhouses.
- Encourage pheromone traps and natural control.
- Strengthen cooperation among universities, researchers and producers.
- Support research into indigenous biological control agents.

Organic and Good Agricultural Practices

- Increase financial support for organic businesses.
- Expand traceability under Good Agricultural Practices.
- Facilitate certified producers' export access.
- Encourage tourism procurement of organic and local products.
- Support carbon and sustainability certification.

Soil Health Protection

- Expand organic matter enhancement.
- Support green manure, rotations and cover crops.
- Apply conservation tillage.
- Encourage composting.
- Establish regional soil biological activity monitoring.
- Plan land use in erosion-prone areas.

4. Conclusion

Environmentally sound input management is strategically important for sustainability, food security, efficiency and climate action, particularly where agriculture and tourism coexist intensively.

Wider adoption can reduce chemical inputs, improve fertility, protect waters, reduce emissions and support biodiversity. It can also strengthen export competitiveness, sustainable tourism and intergenerational resource conservation.

Cooperation among all relevant institutions will be decisive.

5. References

[1] Tarım ve Orman Bakanlığı, Bitkisel Üretim Genel Müdürlüğü, Gübre ve Bitki Besleme İstatistikleri.

[2] FAO (Food and Agriculture Organization), Sustainable Agriculture and Rural Development Reports.

[3] Antalya İl Tarım ve Orman Müdürlüğü, Antalya Tarımsal Üretim İstatistikleri ve Faaliyet Raporları.

[4] DSİ ve Tarım ve Orman Bakanlığı, Antalya Havzaları Yer Altı Suyu Kalitesi İzleme Çalışmaları.

[5] Tarım ve Orman Bakanlığı, Bitki Koruma Ürünleri ve Pestisit Kullanım Verileri.

[6] Avrupa Komisyonu, Farm to Fork Strategy, European Green Deal.

4. Sustainable Agricultural Waste Management

1. Scope and Current Situation

Antalya's total crop production was estimated at eight million tonnes in 2024. Its agricultural output accounts for 20% of Türkiye's fresh fruit and vegetable exports. Field crops and ornamental plants are additional major components [1]. Antalya contains the largest share of national protected cultivation area, at 41%. Open-field and organic farming are also widespread.

This production generates approximately 3.5 million tonnes of agricultural organic waste [2], alongside substantial plastic waste, particularly greenhouse films, irrigation pipes, seedling trays and twine. Sustainable management is not widespread, and small producers commonly resort to uncontrolled burning or dumping.

The sector has a dual structure. Provincial records identify 157,000 farming families, generally operating small, household-labour-based businesses. Large corporate enterprises, particularly in export production, use more advanced technology at higher volumes. Innovation and equitable enforcement therefore require differentiated approaches.

2. Identification of Problems

Antalya's dispersed geography, diverse production and contrasting producer profiles create substantial barriers:

- **Contamination at Source:** Plastic support twine reportedly constitutes approximately one-third of greenhouse waste. Failure to remove it reduces feedstock quality for composting and biogas.
- **Uncontrolled Disposal:** Burning greenhouse residues or dumping them in stream channels has become a persistent practice.
- **Insufficient Incentives:** Family farms receive no adequate compensation for the additional labour required for separation and recovery.

- **Dispersed Production:** Transport from widely scattered small parcels exceeds many producers' financial capacity.
- **Lack of Organisational Infrastructure:** Coordinated communication, recorded collection, transport networks and specialist cooperatives are absent.
- **Seasonal Feedstock Fluctuations:** Summer greenhouse clearance produces surpluses while winter supply declines, preventing continuous, homogeneous feedstock availability.
- **Chemical Residues:** Pesticides can impair anaerobic microorganisms and reduce biogas yields.
- **Agrochemical Packaging:** Uncontrolled disposal of hazardous packaging threatens soil and air quality.
- **Contamination and Processing Costs:** Soil, mud and chemicals on LDPE films, mulch and irrigation pipes substantially increase recycling costs.
- **Unrecorded Burning and Poor Traceability:** The absence of integrated tracking allows valuable plastics to be burned outside licensed systems.
- **Limited Circular Alternatives:** Knowledge and cooperation gaps restrict conversion into biochar, bio-oil, pellets, granules and composites.

These barriers prevent waste recovery potential from being realised and impede modernisation. Poor management causes economic losses, pollution and emissions.

3. Proposed Solutions

Contamination at Source

Producers: Replace plastic support twine and clips with biodegradable alternatives based on jute, hemp or starch.

Public/Private Sector: Prioritise incentives for biodegradable materials. Biomass facilities should accept clean, plastic-free waste only. Improve affordable access and establish local manufacturing where needed.

Uncontrolled Disposal

Producers: Deliver clearance residues to designated temporary collection points.

Public/Private Sector: Municipalities should establish greenhouse waste collection points and enforce dumping and burning restrictions through satellite/drone monitoring and deterrent penalties. Private mobile shredding services can reduce labour burdens.

Insufficient Incentives

Producers: Separate waste and deliver it through registered licensed systems.

Public/Private Sector: Offer cooperative retail, fuel or tax benefits for clean separated waste. Major seedling, seed and fertiliser suppliers should develop circular exchange schemes accepting waste in return for products.

Dispersed Geography

Producers: Coordinate clearance schedules and consolidate waste with neighbouring farms.

Public/Private Sector: Establish transfer stations through metropolitan–district cooperation. Local loading and transport businesses can create employment and provide locally appropriate solutions.

Lack of Organisational Infrastructure

Producers: Request waste management units within existing irrigation or development cooperatives.

Public/Private Sector: Commodity exchanges and agricultural chambers should lead specialist farmer-owned collection cooperatives. Simplify licensing and establish a platform recording waste composition, quantity and location.

Seasonal Feedstock Fluctuations

Producers: Preserve summer surpluses using appropriate on-site ensiling methods under facility guidance.

Public/Private Sector: Invest in drying, pelletising and ensiling to support year-round use.

Chemical Residues

Producers: Observe pre-harvest pesticide schedules and adopt biological control and IPM.

Public/Private Sector: Apply suitable co-digestion recipes combining agricultural, household and animal waste without disrupting microbial communities.

Agrochemical Packaging

Producers: Do not reuse containers; deposit them in dedicated collection units.

Public/Private Sector: Introduce a deposit-return scheme linking new purchases to the return of empty containers.

Contamination and Processing Costs

Producers: Collect films and pipes cleanly in rolls and maintain cleanliness until handover.

Public/Private Sector: Pay higher per-tonne prices for clean, dry plastics to share separation costs.

Unrecorded Burning and Poor Traceability

Producers: Maintain current plastic and chemical use records through the Farmer Registration System (ÇKS).

Public/Private Sector: Establish a Digital Agricultural Waste Passport linking product sales to licensed end-of-life recovery. Manufacturers should integrate affordable QR-code or RFID tracking, supporting access to green transition funds.

Limited Circular Alternatives

Producers: Collaborate to provide attractive feedstock volumes and purity and participate in trials of waste-derived bio-based products.

Public/Private Sector: Establish a platform involving the Provincial Directorate, ATSO, agricultural chambers, Akdeniz University and other capable actors. Set annual circularity targets and prioritise circular intermediate and final products in public procurement.

4. Conclusion

Active communication among all stakeholders is essential. Expected benefits include:

- Preventing approximately 900,000 tonnes of agricultural CO_2 emissions by eliminating open burning.
- Producing an estimated 40,000 tonnes of biochar annually through pyrolysis, contributing to net zero through long-term soil carbon storage or substitution of petroleum-derived fuels.

- Enabling direct recovery of greenhouse residues through biodegradable twine and mechanical separation, potentially preventing the entire associated plastic volume from entering streams, groundwater and the Mediterranean.
- Protecting drinking and irrigation water by preventing leakage from hazardous packaging and contaminated stems.
- Eliminating air pollution from uncontrolled seasonal burning and improving tourism perceptions.
- Processing 160,000 tonnes of greenhouse residues from pilot areas such as Kumluca to supply 40 million kWh annually from a stated installed capacity of 5 MWh. (4)
- Producing organic liquid fertiliser through compost and digestate processing, reducing imported fertiliser dependence and input costs.
- Using biomass pellets and biogas for winter greenhouse heating, reducing coal costs and associated air pollution and climate impacts.
- Reducing plastic shredding and granulation costs by 40% through clean collection and creating local employment.
- Establishing international leadership in sustainable agriculture and waste-to-product technologies.

5. References

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2. Antalya İl Tarım ve Orman Müdürlüğü 2025 Yılı Faaliyet Raporu.pdf

5. Soil Health Protection

1. Scope and Current Situation

Soil is critical to water cycles, plant nutrition and ecosystem functioning. Antalya's sloping and mountainous terrain is vulnerable to water and wind erosion. Intensive cultivation and settlement pressures affect many slopes. Türkiye's climate and topography create high erosion sensitivity, reflected in Antalya's soil losses. Reduced coastal vegetation also increases wind erosion, lowering productivity and impairing water quality through sediment transport.

Soil organic matter (SOM) supports water retention, nutrient balance, biological activity and fertility. Levels are generally low in intensive vegetable and greenhouse production, as in much of Türkiye. High chemical inputs and insufficient residue return contribute to declining SOM, structural degradation and reduced water retention, threatening summer production.

Soil organic carbon (SOC) is a key health indicator. Appropriate management can make farmland a carbon sink, while poor practices create emissions. Mapping in Antalya's basins found average stocks of approximately 48 tonnes C/ha, highlighting the importance of maintaining and increasing carbon.

Sustainable management combines analysis-based fertilisation, precision agriculture, balanced irrigation and integrated land use. The EU Soil Strategy (2021) seeks protection comparable to water, air and marine environments, emphasising monitoring, carbon conservation and erosion reduction. Türkiye and Antalya lack widespread indicator-based systems, and integrated, analysis-based production and irrigation planning remain incompletely adopted.

2. Identification of Problems

Preventing Erosion

- Inappropriate tillage on slopes accelerates erosion.
- Insufficient cover increases runoff and soil loss.
- Coastal wind erosion affects exposed sandy areas.
- Terracing, contour farming and drainage are insufficiently adopted.
- Monitoring and integrated basin management are inadequate.

Increasing SOM

- Organic matter is below critical levels in many areas.
- Excessive inputs impair microorganisms and accelerate decomposition.
- Stubble burning causes carbon and organic matter loss.
- Monoculture degrades balance and fertility.
- Residues are insufficiently recycled.
- Erosion removes organic matter.

Increasing Soil Carbon

- Intensive tillage accelerates decomposition.
- Declining biological activity reduces sequestration.
- Carbon credit and farming mechanisms are underused.
- Technical knowledge and implementation are insufficient.

Sustainable Management

- Analysis-based fertilisation is limited.
- Precision technologies and decision support are underused.
- Irrigation neglects soil–water–climate relationships.
- Regular indicator-based production planning is lacking.
- Farmer knowledge is insufficient.
- Much agricultural waste leaves the system without recovery.

3. Proposed Solutions

Preventing Erosion

- Apply contour farming, terracing and drainage on slopes.
- Encourage permanent cover, cover crops and grasslands.
- Establish suitable trees, shrub barriers and shelterbelts.
- Expand minimum tillage and partial-area cultivation.
- Map sensitivity and implement basin monitoring.

Increasing SOM

- Support manure, compost and vermicompost.
- Incorporate appropriate crop residues.
- Expand green manures, cover crops and rotations.
- Strengthen enforcement against burning.
- Train producers in biofertilisers, biochar and organic amendments.
- Establish cooperative composting.
- Enforce restrictions on damaging practices.

Increasing Soil Carbon

- Encourage reduced tillage, no-till and strip-till.
- Support perennial legumes, grasses and agroforestry.
- Stabilise carbon through biochar and compost.
- Use residues for recovery rather than open burning.
- Provide carbon farming, crediting and offsetting training and incentives.
- Integrate carbon-sequestering green spaces and agroecosystems into planning.
- Expand direct drilling and reduced tillage.

Sustainable Management

- Expand soil- and leaf-based fertilisation and support licensed laboratories.
- Encourage remote sensing, GPS and digital precision agriculture.
- Base irrigation on soil, retention and climate data.
- Establish regional digital monitoring.
- Expand training and advice.
- Integrate soil restoration into rural development and agriculture–tourism planning.

4. Conclusion

Erosion prevention protects long-term productivity and water resources, reducing sediment pollution and flooding. Improved structure and vegetation strengthen adaptation.

Increasing SOM improves fertility, retention, nutrient balance and resilience to erosion and salinity while supporting carbon conservation and quality production.

SOC management reduces emissions, improves moisture retention and supports climate-adapted agriculture.

Integrated, traceable soil management should protect fertile land, food security and resource integrity while reducing costs and strengthening regional resilience in line with EU and national objectives.

5. References

1. T.C. Tarım ve Orman Bakanlığı, “Toprak Koruma ve Arazi Yönetimi Çalışmaları”, Ankara.
2. FAO, “Soil Organic Carbon Management”, Food and Agriculture Organization of the United Nations.
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4. Avrupa Komisyonu, “EU Soil Strategy for 2030”.
5. Antalya İl Tarım ve Orman Müdürlüğü, bölgesel toprak yapısı ve sürdürülebilir üretim verileri.
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7. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Çölleşmeyle Mücadele Ulusal Stratejisi ve Eylem Planı (2019-2030)

6. The Water–Agriculture–Ecosystem Balance

1. Scope and Current Situation

Water is a strategic resource for agriculture. Climate change, population growth, urbanisation, tourism and poor management increase pressure. Agriculture consumes approximately 75% of water used in Türkiye [1], [2].

Antalya combines major agricultural production with approximately 17–18 million annual visitors, creating competition between farming, tourism and ecosystems. It reportedly has approximately 67,000 hectares of greenhouses and hundreds of thousands of irrigable hectares, with high demand in Kumluca, Finike, Demre, Serik, Aksu and Manavgat [3].

Groundwater supplies a substantial share of irrigation. Intensive coastal abstraction causes declining levels and saltwater intrusion [2], [4], with long-term effects documented in Finike and Kumluca [5].

Mediterranean projections indicate high sensitivity to drying. Antalya has reportedly warmed by approximately 1.5–2°C over 50 years, with longer summer droughts and greater evaporation [6], increasing irrigation demand.

Protected cultivation, citrus, tropical fruit and open-field vegetables require considerable water. Surface irrigation persists despite modernisation [1].

Drip systems can save 30–60% relative to conventional surface flooding and improve fertiliser efficiency [3], [9]. Open-field potential remains substantial.

Nitrogen, phosphorus and pesticides affect waters, wetlands and coasts. Integrated management is needed for Köprülü Canyon, Manavgat, Aksu and Demre basins [4], [7].

Efficient irrigation, groundwater management, drought resilience and footprints are increasingly important under EU and national policy [8]. A water footprint represents total direct and indirect freshwater consumption associated with production [10].

2. Identification of Problems

Irrigation Efficiency

- Scheduling does not consistently reflect crop requirements.
- Losses and distribution inefficiencies persist.
- Open canals lose water through evaporation and seepage.
- Weather data are underused.
- Digital infrastructure is insufficient.
- Reclaimed water use is limited.

Groundwater Control

- Unlicensed wells persist.
- Levels decline seasonally.
- Coastal salinity risks increase.
- Recharge zones face development.
- Basin budgets are insufficiently effective.
- Abstraction monitoring is incomplete.

Water Footprints

- Producer records are inadequate.
- Calculations are uncommon.
- Crop-level efficiency analysis is limited.
- Water-intensive crop planning may overlook basin capacity.
- Export sustainability alignment is incomplete.

3. Proposed Solutions

Irrigation Efficiency

- Expand drip and pressurised systems.
- Use moisture sensors and smart irrigation.
- Schedule according to crop water use.
- Accelerate network modernisation.
- Develop safe reclaimed water projects.
- Establish digital management.

Groundwater Control

- Meter all wells digitally.
- Strengthen inspection.

- Protect recharge zones.
- Develop managed recharge.
- Prepare basin groundwater budgets.
- Expand monitoring networks.

Water Footprints

- Expand calculation systems.
- Establish producer-level digital records.
- Align crops with basin budgets.
- Support certification.
- Develop joint agriculture–tourism efficiency programmes.

4. Conclusion

Efficiency can save water, reduce costs and sustain production during drought.

Without sustainable groundwater management, agriculture and drinking water security will be threatened. Footprint management can protect resources and strengthen exports.

Integrated measures can reduce consumption, protect groundwater and wetlands, improve drought resilience, lower costs and reduce sectoral conflicts.

Antalya requires basin-based integrated management involving ZMO, ÇMO, DSİ, the Ministry, local authorities, universities and producers.

5. References

[1] Tarım ve Orman Bakanlığı, Tarımsal Sulama ve Su Yönetimi Politikaları.

[2] DSİ Genel Müdürlüğü, Türkiye Su Kaynakları Yönetimi Raporu.

[3] Antalya İl Tarım ve Orman Müdürlüğü, Tarımsal Sulama Verileri ve Faaliyet Raporları.

[4] Antalya Havza Koruma Eylem Planları.

[5] Akdeniz Kıyı Akiferleri ve Yeraltı Suyu Yönetimi Çalışmaları.

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[7] Tarım ve Orman Bakanlığı, Havza Yönetim Planları.

[8] Avrupa Komisyonu, Water Framework Directive ve European Green Deal.

[9] FAO, Water for Sustainable Food and Agriculture.

[10] Water Footprint Network, Water Footprint Assessment Manual.

7. Climate-Resilient Agriculture and Livestock Production

1. Scope and Current Situation

Climate change directly affects agriculture through warming, irregular precipitation, drought, water stress, extremes and ecosystem degradation. Even small changes can substantially affect yields, quality and continuity [2], [3].

Türkiye is highly exposed within the Mediterranean, and Antalya experiences strong agricultural and livestock impacts. Warming, irregular rainfall, longer droughts, declining groundwater and coastal salinity are documented concerns [4], [5].

Protected cultivation, reportedly covering approximately 67,000 hectares, vegetables, citrus and tropical fruit are economically important but sensitive to summer heat and water demand. Hail, storms and tornadoes threaten structures.

Heat reduces livestock feed intake, milk and meat productivity and welfare, causing substantial losses, particularly in cattle [3].

Pests, pathogens and invasive species expand their ranges, complicating planning. Climate-smart agriculture, water efficiency, agroecology and integrated risk management are consequently gaining importance [2], [3].

2. Identification of Problems

- Longer droughts increase irrigation needs.
- Groundwater declines and salinity increase.
- Extremes damage infrastructure.
- Heat disrupts phenology and yields.
- Planting, flowering and harvest dates shift.
- Pest and disease ranges expand.
- Heat reduces cattle, sheep and goat productivity.
- Feed intake and welfare deteriorate.
- Water-intensive crops become less sustainable.
- Warning and data-driven systems are insufficient.
- Insurance and risk management are underused.
- Producer adaptation knowledge is inadequate.

These threaten food security, rural development and economic sustainability.

3. Proposed Solutions

Crop Adaptation

- Plan using regional projections.
- Expand drought- and heat-tolerant varieties.
- Use precision management.
- Adjust planting and harvesting calendars.
- Encourage agroforestry and mixed systems.

Climate Risk Management

- Expand insurance coverage.
- Strengthen weather and biological warnings.

- Integrate hazard maps.
- Provide digital producer information.
- Develop crisis plans.

Rainwater Harvesting

- Expand farm collection systems.
- Encourage greenhouse roof harvesting.
- Support small storage infrastructure.
- Increase incentives.

Drought and Groundwater

- Monitor abstraction digitally.
- Control irrigation in salinity-prone areas.
- Strengthen basin management.
- Expand efficient systems.
- Align cropping with budgets.

Protected Cultivation and Extreme Weather

- Use storm-, tornado- and hail-resistant structures.
- Expand automated climate control.
- Install emergency ventilation and power.
- Raise resilience standards.

Livestock Resilience

- Expand shading and cooling.
- Support heat-tolerant breeds and genetics.
- Optimise feed and water management.
- Strengthen welfare.

Pests and Phenology

- Improve surveillance.
- Expand biological control.
- Establish digital data systems.
- Strengthen research partnerships.

4. Conclusion

These practices can reduce drought losses, protect groundwater, strengthen infrastructure, reduce livestock losses, conserve ecosystems and improve food security.

Integrated adaptation is an economic and strategic necessity in Antalya and requires coordination among all relevant institutions.

5. References

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[2] IPCC, Climate Change and Land Report.

[3] FAO, Climate-Smart Agriculture Sourcebook.

[4] DSİ Genel Müdürlüğü, Kuraklık ve Su Kaynakları Yönetimi Raporu.

[5] Antalya İl Tarım ve Orman Müdürlüğü, Bölgesel Tarım ve İklim Risk Verileri.

[6] FAO, Food Security and Climate Adaptation Reports.

[7] Academic literature: Studies on climate change impacts and agricultural adaptation in the Mediterranean Basin.

8. Agroecology and Nature-Based Agriculture

1. Scope and Current Situation

Intensive chemical inputs, monocultures and resource pressures in conventional farming create substantial soil, water and biodiversity problems. Agroecology and nature-based agriculture offer sustainable models aligning production with ecosystem processes.

Agroecology treats production as part of ecosystems as well as an economic activity. Nature-based agriculture uses natural processes reflecting water, carbon and nutrient cycles.

Agriculture contributes approximately 20–24% of anthropogenic greenhouse gas emissions globally and is associated with substantial biodiversity loss [1]. Approximately 60% of EU agricultural soils reportedly face risks of organic matter loss and habitat fragmentation [2].

In intensive Turkish agricultural regions, particularly the Mediterranean, SOM is commonly 1.5–2.5%, considered below critical sustainability thresholds [3]. Antalya's protected cultivation, citrus and vegetables place substantial pressure on ecosystems through water use, fertilisers and pesticides.

Nevertheless, its microclimates, biodiversity and year-round production potential offer significant opportunities for agroecological transition. Nature-based models are receiving increasing support under the European Green Deal and Farm to Fork Strategy [2].

2. Identification of Problems

Several environmental and structural challenges within the current production system hinder the agroecological transition:

- Monoculture production systems reduce biodiversity.
- Intensive pesticide and chemical fertiliser use disrupts ecosystem balance.
- Ecological connectivity between agricultural areas and natural habitats is weakening.
- Declines are observed in beneficial insect and pollinator populations.
- Chemical inputs impair soil biological activity.
- Traditional knowledge is insufficiently integrated with modern agroecological practices.
- Economic pressures limit producers' transition to sustainable production.
- Technical training and agricultural extension services on agroecological production are inadequate.

- Ecosystem-based land-use planning is insufficiently implemented.

These conditions threaten both long-term production capacity and the ability of natural resources to regenerate.

3. Proposed Solutions

Nature-Based Production Systems

- Expand production models that mimic natural ecosystem processes.
- Establish ecological corridors and buffer zones within agricultural areas.
- Support agroforestry and multilayer production systems.
- Encourage sustainable techniques that reduce chemical inputs.
- Manage water, soil and biological resources through an integrated approach.

Agroecological Production Models

- Expand crop rotations and diversified cropping systems.
- Integrate biological control into production systems.
- Protect local seeds and genetic resources.
- Integrate organic and good agricultural practices with agroecological systems.
- Support small-scale producers in adopting sustainable production.

Agriculture and Biodiversity

- Implement habitat management in agricultural areas.
- Introduce ecological measures to protect pollinators.
- Strengthen invasive species monitoring and control.
- Reduce agricultural pressure on natural areas.
- Integrate agricultural and nature conservation policies.

4. Conclusion

Expanding agroecology and nature-based agriculture can:

- Reduce chemical input use;
- Protect soil and water resources;
- Support sustainable biodiversity management;
- Increase ecosystem resilience;
- Strengthen climate adaptation capacity; and
- Improve long-term agricultural productivity and quality.

In regions such as Antalya, where high biodiversity coincides with intensive agricultural production, the agroecological transition is strategically important for economic competitiveness and sustainable exports as well as environmental protection. Conserving ecosystem services will be a fundamental determinant of future food security.

5. References

[1] FAO, “Agroecology Knowledge Hub”, Food and Agriculture Organization of the United Nations.

[2] Avrupa Komisyonu, “Farm to Fork Strategy” ve “EU Biodiversity Strategy for 2030”.

[3] Tarım ve Orman Bakanlığı, “Sürdürülebilir Tarım ve Toprak Yönetimi Verileri”, Ankara.

[4] TMMOB Ziraat Mühendisleri Odası, “Agroekoloji ve Sürdürülebilir Tarım Yaklaşımları Raporu”.

[5] Antalya İl Tarım ve Orman Müdürlüğü, bölgesel tarımsal üretim ve biyolojik çeşitlilik değerlendirme verileri.

9. Biodiversity Conservation

1. Scope and Current Situation

Biodiversity encompasses the richness of natural life, including plants, animals, microorganisms and the ecosystems they form. Agricultural production systems are directly dependent on biodiversity. Healthy ecosystems play a critical role in agricultural sustainability through soil fertility, the water cycle, natural pest control, pollination and climate regulation.

In recent years, intensive agriculture, monoculture, habitat loss, pesticide use, unplanned land use and climate change have placed substantial pressure on biodiversity. Intensive interventions intended to increase yields can fragment natural habitats, reduce beneficial organisms and weaken ecological balance.

Türkiye’s geographical position and climatic diversity support substantial biodiversity. Antalya and its surroundings constitute an important centre of Mediterranean ecosystems, with strategic significance for endemic species, natural habitats, pollinators and agriculture. Intensive greenhouse production, tourism, urbanisation and land-use change can nevertheless place pressure on these habitats.

Bees and other pollinators are particularly important to agricultural continuity. However, pesticide use, habitat loss and climate change are increasing the risk of pollinator decline.

Biodiversity conservation, habitat connectivity and nature-friendly production have therefore become strategic priorities in sustainable agricultural policy.

2. Identification of Problems

Current environmental and structural challenges include:

- Monocultures reduce natural species diversity.
- Intensive pesticide use can harm beneficial insects and pollinators.
- Agricultural expansion can cause natural habitat loss.
- Agricultural and settlement pressures fragment ecological corridors.
- Wetlands and other natural habitats face multiple environmental pressures.
- Climate change can alter species distributions and ecological relationships.
- Biodiversity-oriented agricultural planning is insufficiently adopted.
- Local species and genetic resources are inadequately protected.
- Farmers may have limited awareness of biodiversity and ecosystem services.

These conditions threaten the long-term sustainability of natural ecosystems and agricultural production capacity.

3. Proposed Solutions

The following measures should be expanded to conserve biodiversity and strengthen a sustainable balance between agriculture and ecosystems:

Biodiversity in Agricultural Areas

- Expand diversified cropping and crop rotations.
- Strengthen conservation of local seeds and genetic resources.
- Establish buffer zones supporting wildlife.
- Encourage sustainable production with reduced chemical inputs.
- Expand agroecological production systems.

Pollinator Protection

- Strengthen pesticide inspections.
- Restrict practices harmful to pollinators.
- Support beekeeping and natural pollinator habitats.
- Establish flower strips and wildlife corridors.
- Expand scientific monitoring of pollinator populations.

Preventing Habitat Loss

- Incorporate ecological balance into agricultural and settlement planning.
- Develop land-use policies preventing habitat fragmentation.
- Protect wetlands, rangelands and natural ecosystems.
- Strengthen transition zones between farmland and natural habitats.
- Support ecological restoration projects.

4. Conclusion

Expanding biodiversity conservation measures can:

- Strengthen agricultural ecosystem sustainability;
- Support natural pest control;
- Protect pollinator populations;
- Improve soil and water conservation;
- Increase long-term agricultural productivity and quality; and
- Maintain ecological balance.

In biodiversity-rich regions such as Antalya, nature-friendly agriculture is strategically important for rural development, tourism, food security and international competitiveness. Maintaining the balance between production and natural ecosystems is essential to future production security.

5. References

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2. FAO, “Biodiversity for Food and Agriculture”, Food and Agriculture Organization of the United Nations.
3. Avrupa Komisyonu, “EU Biodiversity Strategy for 2030”.
4. Tarım ve Orman Bakanlığı, “Biyolojik Çeşitlilik ve Tarım Politikaları”, Ankara.
5. Antalya İl Tarım ve Orman Müdürlüğü, bölgesel biyolojik çeşitlilik ve tarımsal üretim verileri.

10. Sustainability in Greenhouse Production

1. Scope and Current Situation

Greenhouse cultivation is a strategic production model that increases agricultural productivity by enabling year-round production under controlled conditions. Türkiye is a major country in protected cultivation, while Antalya leads nationally in greenhouse area and production intensity.

Greenhouses are widely used for vegetables, seedlings, ornamental plants and tropical crops, offering high yields and year-round production. However, substantial energy and water consumption, plastic waste and dependence on chemical inputs create significant environmental pressures.

Globally, heating and climate control account for much of protected cultivation’s energy consumption, making carbon emissions a major environmental concern [2]. In Türkiye, intensive groundwater use in Mediterranean greenhouse production places pressure on water resources [1].

Antalya’s abundant sunshine, warm climate and increasing climate impacts make greenhouse cultivation both advantageous and vulnerable. Summer heat and sudden winter weather events threaten infrastructure, while plastic waste and energy costs challenge sustainability.

Sustainable greenhouse production is increasingly being shaped by energy efficiency, water conservation, renewable energy and waste management. This transition is critical to economic competitiveness as well as environmental performance.

2. Identification of Problems

The principal sustainability challenges are:

- High heating and cooling energy consumption;
- Water losses from conventional irrigation;
- Increasing groundwater pressure;
- Pollution from plastic coverings and agricultural packaging;
- Infrastructure risks from extreme heat, storms and hail;
- Limited renewable energy use;
- Poor insulation and efficiency in older structures;
- Insufficient automation and smart greenhouse adoption;
- Inadequate waste and recycling infrastructure; and
- Underdeveloped water and energy monitoring.

These conditions increase costs, intensify resource pressures and weaken long-term sustainability.

3. Proposed Solutions

Greenhouse Energy Efficiency

- Expand energy-efficient designs and well-insulated structures.
- Use thermal screens, shading and heat-loss reduction technologies.
- Optimise consumption through smart automation.
- Support LEDs and efficient equipment.

• Encourage heat recovery.

Water Efficiency

- Expand drip and precision irrigation [1].
- Use moisture sensors and automated irrigation.
- Integrate rainwater harvesting and storage.
- Develop reclaimed water projects.
- Establish consumption monitoring and control.

Greenhouse Waste Management

- Establish recycling chains for plastic coverings.
- Recover organic waste for compost and biofertilisers.
- Ensure controlled disposal of chemical packaging.
- Expand zero-waste practices.
- Establish regional collection and recycling centres.

Renewable Energy

- Expand rooftop solar systems.
- Support geothermal heating.
- Use biomass and biogas as alternative sources.
- Develop hybrid systems and storage.
- Increase financial incentives [3].

4. Conclusion

Expanding sustainable greenhouse practices can deliver:

- Substantial energy reductions;
- More efficient water use;
- Lower environmental burdens from plastic and organic waste;
- Reduced carbon emissions;
- Long-term production cost reductions; and

- More climate-resilient infrastructure.

In Antalya, sustainable greenhouses are strategically important for exports, food security and competitiveness. Energy-efficient, low-carbon systems are fundamental components of future agricultural production.

5. References

[1] Tarım ve Orman Bakanlığı, "Örtü Altı Tarım ve Sürdürülebilir Seracılık Politikaları", Ankara.

[2] FAO, "Greenhouse Horticulture and Sustainable Production Systems", Food and Agriculture Organization of the United Nations.

[3] Avrupa Komisyonu, "Sustainable Greenhouse Farming and Energy Efficiency Policies".

[4] TMMOB Ziraat Mühendisleri Odası, "Türkiye'de Seracılık ve Sürdürülebilir Üretim Raporu".

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11. Rural Development and Sustainable Agriculture

1. Scope and Current Situation

Rural development is a strategic policy area for agricultural sustainability, food security, balanced regional economies and social well-being. Agriculture supports rural employment, natural resource management, ecosystem balance and local economic structures alongside production.

Rural Türkiye faces persistent structural challenges, including small farms, income inequalities and restricted market access. In Antalya, protected cultivation, citrus, fruit growing, livestock and rural tourism underpin the rural economy. However, youth outmigration, weak producer organisation and insufficient value-added production constrain sustainability.

Although small family farms account for a substantial share of production, they face disadvantages in finance, technology and marketing. Sustainable development approaches therefore emphasise cooperatives, local value chains, digital agriculture and rural entrepreneurship, consistent with the European Green Deal and FAO's sustainable development objectives [1], [2], [3].

2. Identification of Problems

- Limited finance for small producers;
- Rising input costs threatening continuity;
- Underdeveloped cooperatives and producer organisations;
- Weak value-added marketing infrastructure;
- Labour losses through migration;
- Declining youth interest in farming;
- Limited digital technology access;
- Weak integration into export and large retail chains;
- Inadequate rural infrastructure and services in some areas; and
- Increasing regional inequalities [1], [3], [4].

3. Proposed Solutions

The following integrated measures are proposed:

Supporting Small Producers

- Strengthen financial support for family farms.
- Expand low-interest loans and grants.
- Increase training, extension and advice.
- Develop dedicated support for young farmers and women.
- Improve digital technology access [1], [2].

Local Production Chains

- Strengthen cooperatives and associations.
- Support branding and geographical indications.
- Expand short supply chains.
- Develop e-commerce and digital marketing.
- Encourage direct sales reducing intermediary costs [2], [4].

Strengthening Rural Economies

- Support agriculture–tourism integration.
- Expand value-added processing.
- Direct renewable investment towards rural areas.
- Improve infrastructure and logistics.
- Plan production around regional development [1], [3], [4].

4. Conclusion

Integrated implementation will:

- Increase small producers' economic resilience;
- Strengthen agricultural sustainability;
- Develop local chains;
- Increase employment;
- Reduce migration pressures; and
- Improve regional economic balance.

In Antalya, rural development policies support social balance and environmental sustainability as well as growth. Strong small producers and local production systems are fundamental to long-term food security.

5. References

[1] Tarım ve Orman Bakanlığı, “Kırsal Kalkınma ve Sürdürülebilir Tarım Politikaları”, Ankara.

[2] TKDK, “IPARD Programı ve Kırsal Kalkınma Destekleri”.

[3] FAO, “Sustainable Rural Development and Smallholder Farming”, Food and Agriculture Organization of the United Nations.

[4] Avrupa Komisyonu, “Rural Development Policy Framework”.

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12. Agriculture–Tourism Interactions

1. Scope and Current Situation

Agriculture and tourism are complementary strategic sectors supporting development, regional prosperity and cultural sustainability. Agriculture provides production and employment, while tourism increases value, market access and visibility. Integrating local products into tourism value chains is an important rural development instrument.

Türkiye’s agricultural diversity, climate and heritage provide substantial potential. Antalya combines intensive vegetable, citrus and fruit production with strong tourism infrastructure and diverse gastronomy.

Nevertheless, local producers have limited integration into tourism supply chains, which rely heavily on standardised, large-scale procurement. Agritourism, gastronomy and rural tourism are developing but remain below desired levels of institutional capacity and adoption.

Short supply chains, local production, gastronomy-led destination management and rural development-oriented tourism are gaining importance. Integration supports environmental sustainability and heritage conservation alongside economic benefits [1], [2], [3].

2. Problems

- Limited direct producer access to tourism markets;
- Inadequate quality standardisation and logistics among small producers;
- Underdeveloped agritourism institutions;
- Weak branding and promotion;
- Underutilised gastronomy potential;
- Insufficient sectoral coordination;
- Uneven rural tourism investment;
- Limited awareness of local production culture;
- Rural infrastructure and service gaps; and
- High intermediary costs [1], [2], [4].

3. Proposed Solutions

The following integrated strategies are proposed:

Agritourism

- Expand farm visits, harvest experiences and rural activities.
- Increase business incentives and support.
- Establish visitor safety and service standards.
- Develop digital promotion and booking.
- Support experience-based rural tourism [3].

Integrating Local Products into Tourism

- Encourage local sourcing by hotels and restaurants.
- Increase visibility of geographically indicated products.
- Strengthen producer–tourism partnerships.
- Expand short supply chains.
- Support promotional events [1], [2].

Gastronomy Tourism

- Integrate regional cuisine into strategies.
- Establish food routes and themed destinations.
- Strengthen chef–producer cooperation.
- Encourage international events.
- Support traditional product conservation [1], [4].

Rural Tourism and Producer Integration

- Improve small producer access to supply chains.
- Strengthen cooperatives.
- Develop digital procurement platforms.
- Support infrastructure and accommodation investment.
- Expand sustainable, environmentally responsible models [2], [3], [5].

4. Conclusion

Stronger integration will:

- Increase producer incomes;
- Accelerate rural development;
- Strengthen regional branding;
- Add value to local products;
- Develop sustainable tourism supply chains; and

- Expand gastronomy and rural tourism potential.

In Antalya, integration is strategically important for cultural heritage and environmental sustainability alongside growth. It is a fundamental driver of regional development and international competitiveness.

5. References

[1] Kültür ve Turizm Bakanlığı, "Sürdürülebilir Turizm ve Gastronomi Politikaları", Ankara.

[2] Tarım ve Orman Bakanlığı, "Kırsal Kalkınma ve Yerel Üretim Destek Programları".

[3] FAO, "Agritourism and Rural Development", Food and Agriculture Organization of the United Nations.

[4] Avrupa Komisyonu, "Sustainable Tourism and Local Food Systems".

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CHAPTER

05

ANTALYA
2050

ANTALYA 2050 / COP31

SUSTAINABLE, LOW-CARBON AND RESILIENT TOURISM

GREEN TOURISM · RESOURCE EFFICIENCY · CLIMATE ADAPTATION

- Low carbon
- Water and energy efficiency
- Resilient destination

A Strategy for Low-Carbon, Climate-Resilient and Sustainable Development by 2050 in Line with the COP31 Vision

1. Sustainable Tourism

Historical Development of Tourism in Antalya

Tourism in Antalya initially developed around nature, the sea, sunshine and history. Cultural heritage sites such as Kaleiçi, Perge, Aspendos, Side, Termessos, Patara and Olympos, together with coastal destinations including Kemer, Belek, Lara, Alanya, Side and Kaş, formed the foundations of its appeal. Following 1980, tourism incentives, expanding air connectivity, large-scale coastal hotel investments and charter flights established Antalya as one of Türkiye's leading tourism centres.

Today, Antalya is seeking to diversify beyond coastal tourism into golf, conferences, sports training camps, health, gastronomy, culture, nature, yachting and cruise tourism. Official figures indicate that the province has 1,885 Ministry- and municipality-certified accommodation establishments, comprising 208,337 rooms and 460,681 beds. This capacity makes Antalya one of Türkiye's largest accommodation centres.

Türkiye's tourism revenue reached a record USD 61.1 billion in 2024, with Antalya among the principal contributors. Antalya's total visitor count for 2024, including transfer passengers, was reported as 17,278,103.

A comparison with the 1980s highlights the remarkable scale of Antalya's tourism growth.

Indicator	1980s	Today (2024–2025)
Total bed capacity	Approximately 20,000–30,000 in the early 1980s, exceeding 80,000 by 1989.	**460,681 beds in Ministry- and municipality-certified establishments.**
Tourist numbers	Approximately 200,000–500,000 annually, increasing rapidly following the introduction of charter flights.	17.3 million visitors (2024).
Tourism revenue	Estimated at approximately USD 100–300 million; the sector was still developing.	Türkiye's total tourism revenue reached USD 61.1 billion, with Antalya accounting for the largest share.
Hotel type	**Small hotels, guesthouses and half-board accommodation.**	**Large resorts, five-star establishments and ultra-all-inclusive accommodation.**
Average length of stay	Longer stays, with tourists more likely to venture beyond their hotels.	Shorter stays, but substantially higher visitor volumes.

The most striking change concerns Antalya's principal competitive advantage. In the 1980s, this was its natural beauty. Today, it is its extensive accommodation infrastructure.

- Bed capacity has increased approximately 15–20-fold.
- Tourist numbers have increased approximately 40–50-fold.
- Tourism has become Antalya's principal source of income.

However, revenue has not increased proportionately. While bed capacity and visitor numbers have expanded rapidly, revenue per tourist has not grown at the same pace.

The principal reasons include:

- The widespread adoption of the all-inclusive model;
- Price competition;

- Package holiday sales; and
- Reduced spending outside hotels.

For example, in the 1980s, tourists would typically:

- Dine in the city centre;
- Shop;
- Use taxis; and
- Visit local businesses.

Today, many visitors can complete their holidays without leaving their hotels. Consequently, record visitor numbers do not generate a proportionate increase in value added across the local economy. Academic studies also identify this as one of Antalya's principal structural challenges.

Tourism Service Concepts: Past, Present and Future

Past: During the early development of tourism in Antalya, accommodation consisted primarily of guesthouses, small hotels, and half-board or full-board establishments. Visitors ventured beyond their hotels and interacted more extensively with city centres, restaurants, local businesses and nearby destinations.

Present: All-inclusive and ultra-all-inclusive packages, themed hotels, resorts, family hotels with water parks, golf resorts and luxury concepts have become prominent, particularly among four- and five-star establishments. Academic studies indicate that the all-inclusive model is widespread in Antalya's accommodation sector and strongly influences visitor preferences.

Future: Towards 2050, tourism services should extend beyond accommodation, meals and access to the sea. Antalya's development should increasingly prioritise:

1. **Sustainable tourism:** Energy, water, waste and carbon management.
2. **Experiential tourism:** Gastronomy, local producers, village routes, archaeological sites and walking trails.
3. **Health and senior tourism:** Long-stay accommodation serving Europe's ageing population.
4. **Digital nomads and long-stay tourism:** Models that strengthen the winter season.
5. **Sports and training camp tourism:** Football, cycling, tennis, golf and triathlon.
6. **Climate-resilient tourism:** Increasingly strategic spring and autumn seasons as summer temperatures rise.

The Twelfth Development Plan also prioritises reducing tourism's environmental impacts, improving water and waste management, increasing energy efficiency, adapting to climate change and advancing the green transition.

Advantages of the All-Inclusive Model for Antalya

The all-inclusive model has provided Antalya with substantial competitive advantages at scale:

- **Higher occupancy and visitor volumes:** Predictable pricing and a convenient, reassuring holiday format have helped attract millions of visitors.
- **Suitability for family and mass tourism:** The model enables cost control, particularly for families with children.

- **Strong distribution through tour operators:** Package holidays have supported Antalya's position in European, Russian and Commonwealth of Independent States (CIS) markets.
- **Visitor satisfaction with price and food and beverage provision:** Academic research in Antalya identifies price, variety and quality of food and beverages among the leading sources of satisfaction for all-inclusive visitors.
- **Support for large-scale investment:** The resort model has enabled the development of substantial bed capacity.

Disadvantages of the All-Inclusive Model for Antalya

The model also presents significant structural risks:

- **Concentration of visitor activity within hotels:** Local restaurants, retailers, taxi operators, guides, souvenir businesses and city centres receive a smaller share of tourism expenditure.
- **Intensified price competition:** Hotels frequently focus on cost reduction rather than quality.
- **Pressure on revenue per visitor:** High visitor volumes may not translate into the desired spending per tourist.
- **Weaker engagement with local culture:** Visitors may primarily experience a constructed resort environment rather than Antalya itself.
- **Greater environmental pressure:** Large facilities require substantial water, energy and food inputs and generate considerable waste.
- **Potential constraints on innovation:** BAKA's Antalya tourism cluster study indicates that the all-inclusive model encourages cost-oriented operations, making product differentiation and innovation more difficult.

2050 Vision

Period	Principal Measure of Tourism Success
1980s	Increasing bed capacity (developing infrastructure).
1990s	Increasing tourist numbers (expanding mass tourism).
2000–2025	Increasing tourism revenue (generating greater foreign exchange earnings).
2025–2050 (COP31 Vision)	Increasing revenue per tourist and value added retained in the local economy; improving water and energy efficiency; and reducing the carbon footprint.

The Objective in the 1980s: Growth

- More hotels;
- More beds;
- More tourists; and
- More charter flights.

This model made Antalya one of the world's largest resort destinations.

In the 1980s, the objective was to expand bed capacity. During the 1990s, attention shifted towards attracting more tourists. From the 2000s onwards, tourism revenue became the principal priority.

By 2050, however, success should be measured through:

- Revenue per tourist;
- Carbon emissions per tourist;
- Water consumption per tourist;
- Value added retained in the local economy;
- Year-round tourism activity; and
- Climate-resilient tourism.

Today's Challenge: Managing Growth Effectively

Antalya's central questions are now:

- How much water does each tourist consume?
- How much energy is used?
- How much food waste is generated?
- What is the carbon footprint per visitor?
- How much does each tourist contribute to the local economy?

From a COP31 perspective, the central question should be how to make the all-inclusive model more sustainable.

Competitive advantages will increasingly include:

- Solar-powered hotels;
- Greywater reclamation;
- Reduced food waste;
- Procurement from local producers;
- Carbon footprint reporting; and
- Zero-waste practices.

This aligns with COP31's emphasis on implementation and sustainable transformation.

Strategic Recommendations for Antalya's 2050 Tourism Plan

Antalya's tourism developed around sun, sea and sand. From a Mediterranean destination with several tens of thousands of beds in the 1980s, it has become a globally competitive destination with approximately half a million beds, large-scale hotels and an extensive all-inclusive model. Its challenge today is to translate visitor demand into greater value added, a longer season, more sustainable consumption and stronger local economic contributions.

Towards 2050, success will depend on retaining the advantages of all-inclusive tourism while reducing its disadvantages, extending activity beyond hotels, adapting to climate change and enabling visitors to experience Antalya itself.

The objectives should include higher revenue, longer seasons, lower environmental pressures and greater local value added.

Principal Strategies for 2050

- **Transform the all-inclusive model.** Antalya's existing market strength developed through this system. It should evolve from unlimited consumption within hotels towards experiences integrated with the surrounding region.
- **Increase spending outside hotels.** Packages should incorporate archaeological site admissions, local restaurant vouchers, village markets, food routes, boat trips, museums and nature walks.
- **Strengthen the winter season.** Continued dependence on summer would increase exposure to extreme heat. Sports, health, conferences, senior tourism and digital nomad models should support year-round activity.
- **Require effective water and energy management.** Municipal climate planning includes a 40% greenhouse gas reduction target by 2030. Tourism facilities should adopt greywater use, solar energy, waste separation, food waste reduction and carbon reporting.
- **Position Antalya as the Mediterranean's sustainable experience capital.** Distinct sub-destination identities should be developed: golf in Belek; nature and marine experiences in Kaş; culture in Side; family tourism in Alanya; nature and sport in Kemer; luxury resorts in Lara; and highland and gastronomic experiences in Elmalı–Korkuteli.

Conclusion

"Over the past 40 years, Antalya has become one of the world's largest tourism destinations. COP31 introduces a new objective: to become one of the world's most sustainable, climate-resilient and high-value tourism destinations."

References

Resmî Kaynaklar: Kültür ve Turizm Bakanlığı, TÜİK, SBB, Antalya İl Kültür ve Turizm Müdürlüğü

Uluslararası Kuruluşlar: UNFCCC, UNRIC, WTTC

Akademik Yayınlar: DergiPark, ResearchGate, CAB International

Bölgesel Raporlar: BAKA, Antalya Büyükşehir Belediyesi

2. A Low-Carbon Tourism Model

1. Scope and Current Situation

The global tourism industry accounts for a substantial share of greenhouse gas emissions through accommodation, transport and food supply chains. Antalya's Sustainable Energy Action Plan (SEAP), which assesses environmental infrastructure and the urban carbon budget, calculated urban emissions at 6,450 $ktCO_2e$ as of 2020 and established a 20% reduction commitment against this reference. Tourism occupies a central position within this inventory.

From an environmental engineering perspective, the ability of accommodation facilities to measure and manage their carbon footprints is a critical green skill. This involves operating equipment efficiently and using analytical methods such as life cycle assessment (LCA) to minimise greenhouse gas generation at source.

At facility level, some Antalya hotels, including Casativo Hotel, have reportedly set footprint ceilings of 38 kg CO_2 per guest-night and electricity targets of 11 kWh per person. A low-carbon tourism model requires integrated engineering transformation addressing embodied building carbon, cooling system thermodynamic efficiency and Scope 3 supply-chain emissions.

2. Identification of Problems

- Hotel footprint calculations are frequently restricted to Scope 1 direct fuel use and Scope 2 purchased electricity, excluding substantial Scope 3 emissions from guest flights, waste disposal and food procurement.
- Greenwashing risks are increasing, with carbon-neutrality claims based on non-standardised methodologies, incomplete ISO 14064 alignment and unverified data.
- Technical staff often lack advanced skills in greenhouse gas accounting, crediting and emissions factor analysis, limiting mitigation to superficial measures such as replacing light bulbs.
- High summer cooling degree days (CDD) create peak HVAC loads supplied by carbon-intensive thermal generation.

3. Proposed Solutions

- Establish IoT-based real-time emissions monitoring covering hotel operational boundaries and employ environmental engineers with data analytics expertise.
- Engage facilities with the Science Based Targets initiative (SBTi) and develop quantifiable, verifiable mitigation pathways consistent with limiting warming to 1.5°C.
- Introduce hyper-local procurement systems drawing on Antalya's agricultural hinterland and use zero-emission food logistics.
- Develop certified regional offset projects, jointly financed by hotels and tour operators, restoring local sinks such as burned forests and seagrass meadows.

4. Conclusion

Low-carbon tourism is an ecological necessity that strengthens destination resilience alongside reducing energy costs. Progress depends on climate awareness across all staff levels and the integration of green skills into operations.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Casativo Hotel Sürdürülebilirlik ve Karbon Ayak İzi Raporları.

3. Green Certification Schemes

1. Scope and Current Situation

Internationally recognised green certification schemes provide a framework for standardising tourism facilities' environmental and ecological performance. Based on Global Sustainable Tourism Council (GSTC) criteria, the Türkiye Sustainable Tourism Programme has initiated mandatory transformation in accommodation.

Published circulars require all establishments holding tourism operation certificates to obtain Stage 2 certification by 31 December 2025. Sectoral adaptation has progressed rapidly: more than 7,000 establishments had completed Stage 1 criteria by November 2023. By September 2025, the number holding full Stage 3 certification, the highest level, had reached 2,005, representing 37% growth in nine months.

From an environmental engineering perspective, certification institutionalises green skills within businesses. Energy efficiency, effluent quality, biodiversity management and emissions control form core components of these standards.

Certification Stage	Current Status / Date	Legal Requirement and Future Target
Stage 1 (Entry Level)	7,000+ establishments (November 2023)	Process completed / Basic criteria
Stage 2 (Development)	Phased transition ongoing	Mandatory by 31 December 2025
Stage 3 (Full Compliance)	2,005 establishments (September 2025)	Full integration by 2030

2. Identification of Problems

- Periodic certification audits, generally conducted annually, prevent the system from detecting deviations or exceedances in facilities' energy, water and waste performance between inspections.
- Sustainability coordinators are often appointed from administrative staff without an environmental engineering background or technical competencies in areas such as fluid mechanics, waste chemistry and process design. This limits their capacity to conduct root cause analyses.
- Some subsidiary certification schemes do not disclose performance indicators transparently, creating a risk that certification will function primarily as an ecolabelling marketing tool rather than deliver measurable environmental improvements.
- Hotel suppliers and subcontractors, including cleaning, landscaping and security providers, are not subject to the same GSTC criteria, leaving environmental burdens entering from outside the facility's system boundary insufficiently controlled.

3. Proposed Solutions

- Certification bodies should move from static reporting towards dynamic certification, with hotel energy analyser, water flow meter and waste weighing data transmitted in real time through application programming interfaces (APIs) to a central Open Environmental Data platform.
- Establish a national green skills accreditation system for sustainability managers in cooperation with university environmental engineering departments, requiring expertise in ISO 14001, ISO 50001 and life cycle assessment (LCA).
- Increase the weighting of measurable sub-indicators, such as a Circular Economy Index, in certification scoring. Require facilities' waste generation per kilogram to remain below the national average as a condition for certification renewal.
- Develop guest–facility interfaces enabling guests to view real-time carbon savings and renewable energy generation shares on in-room digital displays.

4. Conclusion

A substantive sustainability transition requires static certification to evolve into data-driven, dynamic performance monitoring. Given Antalya's extensive bed capacity, certification integrity is a critical safeguard for maintaining the ecological limits of the wider basin.

5. References

Türkiye Cumhuriyeti Kültür ve Turizm Bakanlığı, 2024/5 Sıra Sayılı Genelge. T.C. Kültür ve Turizm Bakanlığı, 2023 Yılı Sürdürülebilir Turizm Verileri. Türkiye Sürdürülebilir Turizm Programı 2025 İstatistikleri ve GSTC Raporları.

4. Water Management in Tourism Facilities

1. Scope and Current Situation

For Antalya, situated within the semi-arid Mediterranean climate zone, water management is a vital dimension of climate adaptation. Academic measurements indicate that direct consumption in accommodation facilities ranges from 103 to 1,209 litres per guest-night, depending on the hotel concept and infrastructure. Detailed analyses found average consumption of 225.4 litres per guest-night in three-star hotels and 205.2 litres in four-star hotels. Golf tourism has one of the highest water footprints among tourism activities.

In destinations such as Belek, annual surface water availability of 130 million m^3 and groundwater potential of approximately 182 million m^3 are under severe hydrological pressure. The impact of municipal wastewater discharges on surface waters is illustrated by chemical oxygen demand (COD) and biochemical oxygen demand (BOD) measurements in the Akarçay Basin, where organic pollution corresponds to Class IV, or highly polluted water.

From an environmental engineering perspective, single-use water management is unacceptable. Treating and retaining water within closed loops through industrial symbiosis, such as reusing hotel effluent for golf course irrigation, is a fundamental green competency.

2. Identification of Problems

- Many facilities collect greywater from washbasins and showers together with toilet blackwater, eliminating opportunities for separate on-site recovery of relatively lightly contaminated water.
- Luxury hotels and golf courses use limited groundwater reserves to irrigate extensive lawns. This can reverse coastal aquifer hydraulic gradients and cause seawater intrusion.
- Sudden summer population growth creates hydraulic and organic shock loads at regional wastewater treatment plants, reducing treatment efficiency and threatening marine receiving environments.
- Facilities with extensive roofs and paved areas lack rainwater harvesting systems, allowing potentially recoverable rainwater to be lost as runoff discharged directly to the sea.

3. Proposed Solutions

- Use separate collection and distribution pipework to segregate guest-room greywater at source, treat it through membrane bioreactors (MBRs) or advanced oxidation processes (AOPs), and reuse it for toilet flushing and landscape irrigation.

- Require golf courses to use 100% reclaimed wastewater, treated through advanced processes including reverse osmosis and UV disinfection, while closing groundwater wells or restricting them to reserve supply.
- Establish per-person water consumption benchmarks and standardise fixtures through low-flow aerators, sensor-operated taps and vacuum flushing systems.
- Harvest rainwater, remove suspended biological material and store it in underground cisterns to meet increased summer landscape irrigation demand associated with evapotranspiration independently of the mains supply.

4. Conclusion

A circular water economy is an essential safeguard for tourism during climate-driven hydrological drought. Water treatment, storage and advanced reclamation system operation are among the most important green skills required by tourism personnel.

5. References

Antalya Bölgesindeki Konaklama Tesislerinde Doğrudan Su Kullanımının İncelenmesi, Mühendislik Bilimleri ve Tasarım Dergisi, 2024. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Akarçay Havzası ve Belek Yeraltı Suyu Rezerv Raporları.

5. Energy Transition in Tourism

1. Scope and Current Situation

Antalya's high summer temperatures mean that tourism energy demand is shaped primarily by thermal comfort, particularly air conditioning and cooling. Energy monitoring indicates that monthly average electricity consumption at large facilities such as Innvista Hotel can reach 64.90 kWh per guest, while annual consumption targets exceed several million kWh. Casativo Hotel, by comparison, has adopted an electricity consumption target of 11 kWh per guest-night.

A principal environmental engineering challenge is the use of carbon-intensive grid electricity from fossil-fuel-based generation, including natural gas and lignite, during sunny summer periods of peak cooling demand. Regional energy consumption patterns and the target of reducing total emissions of 6,450 $ktCO_2e$ by 20% require an urgent transition towards a prosumer model using hotel roofs, parking areas and landscaped spaces. Renewable integration and storage can directly support the prevention of climate-altering emissions.

2. Identification of Problems

- Flat roofs are occupied by chillers and air-handling units, reflecting architectural and aesthetic considerations that leave limited space for photovoltaic (PV) installations.
- Hotels remain dependent on high-emission fuel oil, LNG or natural gas boilers, particularly for domestic hot water and winter heating.
- Battery and thermal storage systems capable of shifting daytime solar surpluses to night-time lighting and cooling are perceived as having high capital costs.
- Guest-controlled room air conditioning may continue operating with balcony doors open, causing thermal energy losses and substantial indirect emissions.

3. Proposed Solutions

- Replace conventional fossil-fuel boilers with high-efficiency air-, ground- or water-source heat pumps with a coefficient of performance (COP) of at least 4, completing the electrification process.
- Introduce building-integrated photovoltaics (BIPV), incorporating electricity-generating panels into façades, balcony shading and solar carports.
- Use phase change materials (PCMs) for thermal storage. Surplus midday solar electricity can cool water or produce ice, reducing night-time chiller compressor loads.
- Install AI-enabled building management systems (BMS), supported by outdoor temperature and humidity measurements used to determine air enthalpy, to optimise HVAC operation autonomously.

4. Conclusion

Energy transition involves redesigning buildings' thermal performance and energy boundaries as well as acquiring equipment. Combining Antalya's solar resource with renewables, efficiency and green skills provides a principal pathway towards carbon-neutral tourism.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Casativo Hotel Sürdürülebilirlik ve Karbon Ayak İzi Raporları. Innvista Hotel Sürdürülebilirlik Politikası ve Enerji Tüketim Verileri.

6. Waste Management and Circular Tourism

1. Scope and Current Situation

Mass tourism, particularly the all-inclusive model, generates per-capita solid waste volumes that place substantial pressure on regional carrying capacity. Waste management is one of six principal mitigation areas identified in Antalya's SEAP reports. The substantial biodegradable waste generated by millions of summer visitors undergoes anaerobic decomposition in landfills, producing methane (CH_4), a greenhouse gas with a warming effect stated as 28 times that of CO_2.

Weaknesses in terrestrial waste management also affect marine ecosystems. Volunteer divers removed one tonne of waste from the seabed at Demre Çayağzı Harbour within a few days. Plastic packaging is a major source of microplastic pollution. Operational targets such as Casativo Hotel's "11 kg Domestic Waste" reduction target demonstrate the need to equip staff with skills that prevent waste at source.

1. Identification of Problems

- Buffet-based all-inclusive operations generate substantial avoidable food waste that is not composted.
- Toiletries, straws and beach beverage containers use low-quality single-use plastics with near-zero recycling rates because of their low economic value.
- Paper, glass, metals and plastics separated in colour-coded bins are mixed again during collection because of logistical shortcomings.

- Renovation debris and discarded furniture are sent directly to disposal sites rather than recovered through upcycling and circular practices.

2. Proposed Solutions

- Install on-site or regional in-vessel composting systems and return the resulting organic fertiliser to landscaped carbon sinks and local agriculture.
- Adopt circular procurement, replacing individual toiletries with refillable dispensers and disposable PET bottles with reusable glass bottles supplied through appropriately treated drinking water systems.
- Digitalise waste monitoring, using smart kitchen scales and AI-enabled cameras to identify frequently wasted foods and optimise menus and portions.
- Install reverse vending machines (RVMs) near beaches and pools, rewarding correct returns with on-site spending credits or tokens.

3. Conclusion

Waste management is an engineering and materials discipline that plans the material life cycle from design to consumption. Successful zero-waste facilities require full adoption of green skills that recognise waste as a resource.

4. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Casativo Hotel Sürdürülebilirlik ve Karbon Ayak İzi Raporları. YatMarina, Demre Çayağzı Limanı Dip Temizliği Faaliyet Raporları.

7. Ecosystem Conservation in Tourism Areas

1. Scope and Current Situation

Antalya lies at the intersection of terrestrial forests and diverse Mediterranean coastal habitats. Its coasts, bays, national parks and protected sites constitute core tourism assets. According to Foundation for Environmental Education data, Antalya maintained its global leadership with 232–233 Blue Flag beaches in 2024 and 2026. Intensive use nevertheless creates significant physicochemical pressures.

The Turkish Marine Research Foundation's (TÜDAV) project on climate adaptation for Antalya's marine and coastal areas reports sea-level rise, acidification, warming and destructive biodiversity impacts from Lessepsian invasive species arriving through the Suez Canal, including lionfish and pufferfish. Coastal tourism sustainability depends directly on the ecological health of critical habitats such as endemic *Posidonia oceanica* meadows and loggerhead turtle (*Caretta caretta*) nesting sites. Nature-based tourism requires environmental competencies capable of assessing ecosystem service values.

2. Identification of Problems

- Uncontrolled anchoring by excursion boats and yachts physically damages seagrass, an important Mediterranean carbon sink and oxygen source.
- Intensive coastal hotel lighting causes phototactic disorientation in turtle hatchlings, preventing them from reaching the sea.

- Nitrogen and phosphorus in inadequately treated hotel discharges and agricultural runoff cause eutrophication in sheltered bays and deplete bottom-water oxygen.
- Altered seawater temperature regimes weaken native species and enable invasive species to disrupt marine food webs.

3. Proposed Solutions

- Establish carrying capacities for sensitive bays and seagrass areas and install permanent eco-mooring systems that prevent anchor damage.
- Replace beach lighting with low-intensity, wavelength-optimised red or amber LEDs and use motion sensors to eliminate coastal light pollution during breeding seasons.
- Install smart oceanographic buoys measuring pH, dissolved oxygen, temperature and salinity in real time, transmitting biodiversity stress indicators to local authorities.
- Require facilities to allocate budgets and green-skilled personnel to dune stabilisation and native species conservation alongside Blue Flag requirements.

4. Conclusion

Depleting ecological capital undermines a tourism destination's viability. Antalya must support biodiversity through active restoration engineering and rigorous marine conservation, treating nature as an asset requiring stewardship.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. TÜDAV - Antalya'nın Deniz ve Kıyılarının İklim Değişikliğine Adaptasyonu Projesi. TÜRÇEV Mavi Bayrak 2024 İstatistikleri. TÜRÇEV Mavi Bayrak 2026 İstatistikleri.

8. Climate-Resilient Tourism

1. Scope and Current Situation

The climate crisis presents physical threats through extreme heatwaves, prolonged droughts, flash flooding and sea-level rise. TÜDAV identifies substantial adaptation requirements for the coastal infrastructure underpinning Antalya's tourism. Changes in climatic comfort are also reshaping tourism's geographical and seasonal distribution.

Extreme July heat stress can cause cancellations. AKTOB reports, meanwhile, indicate that Russian, German and British demand continues strongly from September, even after schools reopen, with an objective of extending the season into the third week of November where weather permits. Resilience nevertheless requires reassessment of buildings, supply systems and health risks, including tropical diseases. Environmental engineering must make buildings capable of withstanding extreme conditions.

2. Identification of Problems

- Facilities designed using historical climate data experience façade overheating and cooling system failures during current heatwaves.
- Buildings immediately adjacent to beaches face erosion and saltwater corrosion affecting foundations, pools and underground parking.

- Visitors and outdoor workers face heatstroke, dehydration and humidity-related respiratory difficulties.
- Warming increases risks from mosquito-borne diseases such as West Nile virus infection and dengue, affecting destination safety and travel insurance.

3. Proposed Solutions

- Expand high-albedo cool roofs and vegetated façades to lower surface temperatures and mitigate urban heat islands.
- Develop nature-based coastal protection, including mangrove-like wetland planting and artificial reefs, in response to projected sea-level rise.
- Map climate risks, upgrade drainage at flood-prone facilities and relocate low-lying wastewater pumping stations to higher elevations.
- Train staff in disaster triage and climate-related health risks, enabling hotels to function as safe assembly areas and cooling centres during extreme events.

4. Conclusion

Resilient tourism requires destinations to possess the capacity to absorb and recover from ecological shocks. Adaptation investment is a necessary and rational safeguard against future damage.

5. References

TÜDAV - Antalya'nın Deniz ve Kıyılarının İklim Değişikliğine Adaptasyonu Projesi. Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri.

9. Carbon Emission Reduction in Tourism Transport

1. Scope and Current Situation

Transport is a major contributor to tourism’s environmental footprint. International aviation is addressed through global regulation and offsetting arrangements and lies largely outside local authorities’ direct influence. Destination mobility, including airport transfers, urban trips and archaeological site excursions, nevertheless strongly affects urban emissions. Road transport for the 12.8 million tourists arriving by September relies on an extensive diesel fleet of buses, premium minibuses and taxis.

Fossil fuel combustion releases particulate matter ($PM_{2.5}$ and PM_{10}) and nitrogen oxides (NO_x), substantially impairing air quality. Sustainable mobility requires a transition from inefficient internal combustion engines towards electric and hydrogen-based zero-emission networks.

2. Identification of Problems

- Tour operator fleets are almost entirely fossil-fuel-based, with congestion along airport–hotel corridors to Belek, Kemer and Alanya increasing emissions.
- Insufficient AC and DC fast charging at hotels and attractions limits electric vehicle rental uptake.
- Cycling and micromobility lack safe, continuous, integrated infrastructure.
- High-capacity low-carbon options such as rail and electric bus rapid transit do not fully serve major tourism areas.

3. Proposed Solutions

- Develop phased transition plans jointly with authorities and industry, encouraging fully electric or green-hydrogen fuel-cell airport transfer fleets.
- Make PV-canopy-powered smart charging an advanced mandatory criterion in green certification.
- Designate low-emission zones along coastal areas and in historic districts such as Kaleiçi, permitting only electric vehicles and micromobility.
- Provide hotel e-bike and e-scooter fleets charged through renewable generation to support local exploration.

4. Conclusion

Decarbonising tourism transport is essential to climate targets and to improving destination appeal through reduced noise and air pollution. Electrification is a concrete urban transformation capable of strengthening Antalya's competitiveness.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri.

10. Digitalisation and Tourism Management

1. Scope and Current Situation

As an extension of Industry 4.0, digitalisation provides the underlying engineering infrastructure for sustainability. Sectoral figures indicate more than 6.25 million arrivals in the first half of 2025, rising to 12.8 million by mid-September. Managing this scale requires predictive, data-driven models. New AI-related key performance indicators, including Token Cost per Guest (TCPG), are being discussed.

Smart destinations process large datasets on water pollution, electricity demand, air quality and traffic to optimise activities contributing to climate change. Engineering teams require digital green skills in algorithmic thinking, sensor interpretation and system optimisation.

2. Identification of Problems

- Monthly billing delays access to consumption data, preventing immediate responses to bursts, abnormal electrical loads and automation faults.
- Fragmented visitor data prevent real-time identification of carrying capacity exceedances.
- Manually controlled or fixed-timer heating, cooling and lighting cannot respond dynamically to weather and occupancy changes.
- Sustainability and footprint data are not transparently shared through digital channels, limiting environmentally responsible visitor behaviour.

3. Proposed Solutions

- Establish an urban digital twin integrating energy, water, transport and waste networks to simulate seasonal infrastructure pressures and anticipate crises.

- Install IoT visitor monitoring at attractions and sensitive sites, using anonymised Wi-Fi tracking or thermal cameras to support real-time carrying capacity management.
- Deploy machine-learning-enabled BMS to determine storage and pre-cooling or heating strategies using forecast weather and occupancy.
- Develop guest applications displaying renewable generation and rewarding water-saving behaviour through gamification.

4. Conclusion

Digitalisation enables the collection and conversion of data into actions that reduce carbon emissions and water consumption. It can make Antalya a flexible, smart and data-driven climate-resilient city.

5. References

Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri. Turizm Gazetesi, Antalya Turist Sayısı ve Yapay Zekâ Gelişmeleri Güncel Verileri.

11. Tourism Carrying Capacity and Overtourism

1. Scope and Current Situation

Tourism growth can develop into overtourism when ecological and spatial thresholds are exceeded. Antalya contains more than one-third of Türkiye's tourism-certified bed capacity. More than 12.8 million arrivals by mid-September, concentrated along Kemer, Manavgat and Alanya, place pressure on infrastructure and environmental assimilative capacity.

Reported bed capacity increases of 5–8% between 2024 and 2025 imply greater abstraction, electricity demand and waste generation. Carrying capacity analysis considers treatment capacity, carbon sequestration and sustainable groundwater abstraction without salinisation.

2. Identification of Problems

- Continuous coastal development risks overwhelming treatment and disposal infrastructure during July and August.
- Simultaneous visitor pressure in parks, dunes and waterfall areas compacts soil, reduces porosity and damages vegetation.
- Congestion and noise reduce visitor experience and residents' quality of life.
- Environmental impact assessments insufficiently address cumulative basin-wide effects.

3. Proposed Solutions

- Revise tourism master plans using basin-based maximum bed capacity maps and introduce temporary restrictions on new hotels or rooms where limits are exceeded.
- Apply dynamic pricing and digital quotas in overcrowded protected areas to distribute demand.
- Encourage inland and rural agritourism, ecotourism and cultural routes to decentralise pressure.
- Design buffers reducing conflicts between resident recreation and tourism and introduce destination and carrying capacity levies to compensate infrastructure costs.

4. Conclusion

Exceeding carrying capacity undermines the resources sustaining tourism. A durable economy requires a high-quality, manageable visitor economy operating within ecological limits.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Akarçay Havzası ve Belek Yeraltı Suyu Rezerv Raporları. Turizm Gazetesi, Antalya Turist Sayısı ve Yatak Kapasitesi Güncel Verileri.

12. Social Sustainability in Tourism

1. Scope and Current Situation

Social sustainability is as important as tourism's environmental performance. Antalya is an international tourism centre, Türkiye's leading province in crop-production income and its fifth most populous province. However, major investment does not consistently translate into integrated local development.

Stage 3 certification based on GSTC standards addresses cultural heritage and social justice alongside environmental management. Working conditions, seasonal insecurity and local procurement remain major concerns.

From a social life cycle assessment perspective, green skills improve technical capacity and professional status, contributing directly to employees' economic and social well-being.

2. Identification of Problems

- Seasonal employment, largely April–November, limits continuous social protection and institutional sustainability culture.
- Tourism-related inflation, housing shortages and rents displace staff towards low-quality accommodation.
- Procurement from major national or international wholesalers increases food miles and weakens agriculture–tourism synergies.
- Exclusion of residents, fishers and local businesses from decisions disrupts the balance between tourism and everyday life.

3. Proposed Solutions

- Encourage direct procurement of low-footprint food and textiles from regional cooperatives through local purchasing quotas.
- Develop energy-efficient green staff housing with wastewater and greywater reuse and adequate thermal comfort.
- Provide certified winter training in resilience, waste management and carbon accounting through universities and TÜRÇEV.
- Ensure transparent independent scrutiny of social certification indicators by unions and civil society and require accessible environmental events for residents.

4. Conclusion

Environmental objectives depend on social sustainability. Waste, treatment and optimisation systems require motivated, adequately supported and technically skilled employees.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. Türkiye Cumhuriyeti Kültür ve Turizm Bakanlığı, Türkiye Sürdürülebilir Turizm Programı İstatistikleri. Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri. Antalya Deniz Çöpleri İl Eylem Planı (2021) ve Tarımsal Faaliyet Verileri.

13. Sustainable Marinas and Marine Tourism

1. Scope and Current Situation

The Mediterranean's enclosed, sensitive waters are directly affected by maritime and marina activities. Antalya leads with 232–233 Blue Flag beaches, six marinas and 13 tourism boats in the cited 2024 and 2026 figures. Its coast hosts numerous marinas and fishing shelters, including Setur, Finike and Makmarin.

Despite substantial control efforts, marine tourism pollution includes complex chemicals as well as litter. The removal of one tonne of waste at Demre Çayağzı illustrates continuing weaknesses. Oily bilge water, ballast, greywater, blackwater and toxic antifouling coatings threaten harbour chemistry and oxygen conditions.

2. Identification of Problems

- Reception capacity, pumping limitations and costs contribute to illegal blackwater discharge in isolated bays.
- Hull washing, sanding and painting release metals and toxic substances through drainage.
- Small hydrocarbon leaks form surface films affecting light penetration and oxygen exchange.
- Sampling-based inspections do not continuously capture pollution fluctuations, and telemetry infrastructure remains incomplete.

3. Proposed Solutions

- Integrate the Blue Card wastewater tracking system with GPS-linked tank monitoring sensors to detect and sanction illegal discharges in real time.
- Collect maintenance-area runoff and treat it through closed-loop ultrafiltration and activated carbon adsorption, targeting complete toxic biocide removal.
- Require heavy-metal-free silicone, fluoropolymer-based or biomimetic alternatives to conventional antifouling coatings.
- Expand renewable shore power so berthed vessels can switch off diesel generators.

4. Conclusion

Marine tourism must conserve the ecosystem on which it depends. Advanced treatment, alternative materials and rigorous digital monitoring are essential to protecting Antalya's coastal quality and Blue Flag reputation.

5. References

Antalya Deniz Çöpleri İl Eylem Planı (2021) ve Güncel Temizlik Faaliyetleri Raporları (Setur, Finike vb.). TÜRÇEV ve FEE Mavi Bayrak 2024 İstatistikleri. TÜRÇEV ve FEE Mavi Bayrak 2026 İstatistikleri.

14. Climate Finance in Tourism

1. Scope and Current Situation

Transitioning to low-carbon, circular and resilient facilities requires substantial capital expenditure. Certification requirements under Türkiye's Sustainable Tourism Programme generate demand for automation, treatment, solar and efficient HVAC investment. Coastal protection, beach nourishment and infrastructure adaptation also involve high costs.

Financing can be constrained by longer payback periods and smaller investors' creditworthiness. Green bonds, environmental, social and governance (ESG) funds and sustainability-linked loans are needed to support Antalya's transition.

2. Identification of Problems

- Small and medium-sized establishments face administrative barriers to affordable finance.
- Standardised measurement, reporting and verification systems for environmental investment outcomes are insufficient.
- Short-term profitability priorities discourage equipment with five- to seven-year paybacks.
- Municipal capacity to develop projects for international climate funds is limited.

3. Proposed Solutions

- Encourage energy performance contracts and ESCO models, with service providers financing improvements and recovering costs through verified savings.
- Allocate a proportion of accommodation taxes or environmental contributions to an Antalya Green Tourism Fund supporting circular investment.
- Offer sustainability-linked interest reductions to hotels achieving emissions thresholds or Stage 3 certification.
- Introduce tax provisions favouring green technologies, including accelerated depreciation for solar and wastewater recovery.

4. Conclusion

Climate finance is essential to implementation. Appropriate capital allocation, interest rates and repayment periods can prepare Antalya's infrastructure for future hydrometeorological risks.

5. References

Türkiye Cumhuriyeti Kültür ve Turizm Bakanlığı, Türkiye Sürdürülebilir Turizm Programı İstatistikleri. TÜDAV - Antalya'nın Deniz ve Kıyılarının İklim Değişikliğine Adaptasyonu Projesi. Türkiye Sürdürülebilir Turizm Programı 2025 İstatistikleri ve GSTC Raporları.

15. Resilient Tourism Cities and Disaster Management

1. Scope and Current Situation

Modern environmental risk management combines mitigation with systemic adaptation. Antalya faces sea-level rise, erosion, storm flooding and prolonged heatwaves. TÜDAV highlights the physical damage caused by sudden meteorological and hydrological shocks.

A destination operating into late November requires continuous disaster management for storms, floods and summer fires. Resilience encompasses infrastructure, visitor health, vector risks and rapid recovery.

2. Identification of Problems

- Drainage cannot accommodate increasingly intense rainfall, flooding hotel ground floors.
- Rigid coastal structures can accelerate erosion and ecological degradation.
- Integrated multihazard warning and evacuation networks linking hotels, airports, hospitals and authorities are incomplete.
- Warming may enable new vectors and tropical diseases, affecting health and insurance.

3. Proposed Solutions

- Prioritise dune restoration, artificial reefs and beach nourishment to dissipate wave energy.
- Test facilities for hydrological and structural vulnerability and integrate climate-resilient building classifications into zoning regulations.
- Provide regular evacuation, first aid, triage and logistics training and simulations.
- Establish integrated ecological vector management networks involving health and environmental services.

4. Conclusion

Disaster resilience is essential to business continuity and visitor safety. Proactive engineering and competent crisis management must enable Antalya to absorb climate shocks and maintain functioning.

5. References

Antalya İli Sürdürülebilir Enerji Eylem Planı (SEAP) ve Kentsel Salım Envanteri. TÜDAV - Antalya'nın Deniz ve Kıyılarının İklim Değişikliğine Adaptasyonu Projesi. Akdeniz Turistik Otelciler ve İşletmeciler Birliği (AKTOB) 2024-2025 Turizm Verileri.