Adaptation of the water-energy system to climate change: National Study - Morocco

Final report

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Contents

Key messages

- Climate change is a reality in Morocco, and its effects on our environment are already visible. The significantly lower rainfall levels recorded over the last thirty years have seriously curtailed dam inflow rates, resulting in low reservoir fill rates. This situation has led to limited intensification of agriculture, and hence low returns on the capital invested in water infrastructure and increased use of groundwater, leading to overuse.

- Energy production has clearly suffered the impact of climate change, reflected in decreased water reserves and smaller heads across all dams. It has been estimated at barely 50% of the objective established by studies for the Moroccan "Integrated water resource development plans" (PDAIREs). This means that the water sector is consuming more energy than it produces.

- Forecasts are not optimistic. Climate change models indicate that rainfall could drop by over 20% by 2050, while evaporation and variability are set to increase (Wilby 2007). This would further aggravate water shortages across Morocco's drainage basins.

- Morocco has limited options for tapping into additional resources. Virtually all runoff into the country's rivers is already accounted for, with 128 large dams and several smaller structures (World Bank 2007a; World Bank 2007b). The additional volume of water stored following the planned construction of 59 further dams will be very limited.

- Taking into account the future impact of climate change which is expected to reduce water input by almost 30% (due to a 15% drop in rainfall) and an increase in evaporation risks further reducing the contribution of planned dam and water transfer projects.

- If the business-as-usual scenario for water resource management, which involves continuing to construct structures to exploit water, overuse groundwater and conduct programmes to protect and enhance water resources (reducing pollution, water conservation, development of river basins, etc.) at the low rate of recent years, it will have a negative impact on economic and social development and on the environment in Morocco. This scenario is likely to produce only limited results, possibly even reducing the added value currently generated by the water sector (stagnation in growth of agricultural land apart from the areas covered by the Al Wahda and Dar Khrofa dams), a slight increase in drinking water and hydropower production, a shortage of groundwater in some regions along with impairment of its quality, lower quality water resources, drying-up of springs and shrinking wetlands areas.

- The main challenge which Morocco will need to face in the coming decades will be adapting to a decrease in renewable water resources. It will have to manage these resources carefully, establish an effective and transparent mechanism for allocating resources and ensure that water transport infrastructure minimises loss and is flexible enough to respond to the most important demand. Surface water quality will need to be improved and groundwater protected against seepage by encouraging municipal and industrial investment in sanitation and by applying environmental legislation to companies and public bodies which discharge wastewater. One positive step would be the adoption of an innovative set of public policies aimed at curbing water consumption.

- Exploiting non-conventional water resources will constitute a key component of future water policy. Sea water desalination could become a new strategic source of water in urban areas close to the coast and the reuse of treated sewage could boost the amount of water available locally for irrigation in tourist centres and possibly in agriculture. These new technologies, however, will not suffice to bridge the growing divide between supply and demand, and managing demand is therefore an urgent priority. All things considered, saving water represents the most economical resource available, whether for irrigation or drinking water.

- Developing non-conventional resources and managing water demand would further drive up energy consumption in the water sector, which would account for almost 10% of the country's consumption and should be included in Morocco's energy demand as of now.

- The water sector in Morocco has to date paid scant attention to the issue of climate change and is often unaware of its impact on future water resources. Studies will be needed to assess the impact and cost of climate change and draw up adaptation solutions.

- The widespread use of modern irrigation systems is likely to lead to surging energy needs in the agricultural sector. Switching towards currently available and efficient technological options such as underground irrigation using porous pipes would make for major savings of both water and energy as a result of their enhanced irrigation yield and lower pressure requirements (0.6 Bar instead of 3 Bar for drip irrigation). Moreover, the revolution in renewable energy (wind, biomass and solar power) in terms of technological development and costs may help reduce the consumption of fossil fuels by fostering decentralised renewable energy projects for driving pumping stations.

- Investment forecasts for the production of electricity will require the equivalent of the water consumed by a population of about 3 to 4 million inhabitants in order to meet the cooling needs of inland thermal power stations by 2030. When returned to the environment, the quality of this water has been impaired through heating. More co-ordinated planning and action will consequently be required between the water and energy sectors if further aggravation of the water deficit is to be avoided.

- Water requirements in the phosphates sector will rise from the current level of 66 Mm^3 per year to over 158 Mm^3 per year in 2030. The amount of water consumed per tonne of phosphate concentrate produced is between 1 and 3 m^3. The OCP Group's development strategy takes account of this demand. In order to safeguard strategic groundwater resources, growth in the phosphates industry will be achieved on the back of constant levels of freshwater abstraction, through the following actions: i) geographical reallocation of water abstraction to the upper Oum Er Rbia basin; ii) sea water desalination and wastewater treatment to meet emerging needs..

- In the interests of a better energy future for Morocco, a new energy strategy has been drawn up on the basis of realistic technological and economic options. The strategic objectives are aimed at securing the energy supply, ensuring availability and accessibility of energy at the lowest possible cost and reducing energy dependence by diversifying energy sources, achieved through developing the national energy potential and promoting energy efficiency in all economic and social activities. Morocco has thus set itself an achievable energy efficiency potential of 12% by 2020, and a share of renewable energy in the national energy balance of between 15 and 20%. By this date, the share of solar, wind and hydroelectric power will represent about 42% of installed capacity (14,580 MW) compared to 26% in 2008 (5,292 MW).

Summary

It is currently estimated that Morocco has an average annual natural water resource potential of almost 22 billion m³, of which approximately 18 billion m³ is surface water and 4 billion m³ is groundwater. Natural resources are verging on the threshold of 500 m³ per capita per year, widely recognised as the absolute scarcity threshold meaning that the country is likely to face a permanent water shortfall.

Developing this potential has always been a key concern for Moroccan economic policy, given its strategic role in the development of irrigated agriculture as well as the country's water and food security. Considerable water infrastructure has been set up, exploiting almost all economically exploitable natural water resources. These efforts, extending over the past four decades, have made it possible to:

- Satisfy demand for and secure the supply of drinking water to most towns in Morocco, even during periods of drought;
- Develop large scale irrigation over approximately 1.6 million ha. This contributes to between 45% and 75% of the country's agricultural production depending on rainfall in a given year, and 75% of agricultural exports. It also provides almost 120 million days of work and encourages regional and local development;
- Develop the agri-food industry (13 sugar refineries, 13 dairies, hundreds of agri-food packaging and processing plants);
- Produce hydropower thanks to the plants associated with the dams. Studies for the PDAIREs have assessed this production at almost 3,500 GWh per year.

These developments are currently facing new challenges, including:

- The overuse of groundwater and disruption of the balance which existed between traditional abstraction and the possibilities for natural recharge. This has led to a drop in groundwater levels, reduced flow with some springs even drying up, disruption to water supply in traditionally irrigated sectors and the deterioration and decline of traditional irrigation and oases. This trend may well be exacerbated in the future with water resources expected to dwindle as a result of climate change;
- Limited water use efficiency: irrigation systems and drinking water supply networks are far from efficient and are responsible for the loss of large volumes of water;
- An alarming deterioration in water quality as a result of delays in building sanitation and wastewater treatment systems;
- The rate at which dam capacity is being lost as a result of silting;
- Significantly less rainfall due to climate change. This decrease has had a major impact on dam levels. Successive droughts over the last 30 years have significantly reduced dam inflow rates (1970-2000 average 20% to 50% down on 1945-70), reflected in reservoir fill rates (50% down according to a 10-year average) and major shortfalls in the supply of irrigation water (52% down according to a 10-year average). This situation leads to an energy production shortfall of almost 1,200 KWh (50% of the objective established in improvement studies) and limited intensification of agriculture and hence low returns on the capital invested in water infrastructure.

Scientific investigations carried out on climate projections in Morocco (Wilby 2007) have shown that climate change is likely to result in:

- An increase in summer temperatures of up to 1.8°C by 2020, 3.7°C by 2030 and 6.2°C by 2080;
- A reduction in rainfall in the region of 5% to 15% by 2030 and 10% to 25% by 2050.

The 3°C increase in temperature and 15% reduction in rainfall by 2030 would substantially reduce annual runoff and consequently the volume of water used by existing and planned dams. Analysis of droughts observed over the last thirty years shows that the deficit in runoff is around double that recorded for precipitation.

In terms of prospects, river basin water balances, which compare available resources with water demand in order to establish a representative picture of the water situation, indicate that most basins will be in deficit by 2030. The following table summarises the results of the water balances for scenarios with and without the impact of climate change covered by tables 18 and 45.

Table 1 - Summary of water balances with and without the impact of climate change

	Climate change not taken into account		Climate change taken into account	
	2030	2050	2030	2050
Water demand (Mm³/yr)	13,044	13,269	13,608	14,397
Water resources (Mm³/yr)	12,212	12,694	9,820	9,005
Overall deficit (Mm³/yr)	-832	-575	-3,788	-5,392
Number of basins with water deficits taking into account use of non-conventional resources (Out of 9)	6	4	7	7
Number of basins with water deficits not taking into account non-conventional resources (Out of 9)	7	8	9	9

These solutions feature high levels of energy consumption, as is the case with sea water desalination and the water transfer project, for example. Water sector consumption is expected to increase from around 1,450 GWh in 2010 to around 6,145 GWh in 2030 (0.7 to 0.8 kWh/m³) - four times current consumption. Table 2 shows the volumes pumped and energy consumption.

Table 2 - Energy consumption in GWh

Sector	2010		2030	
	Water (Mm³)	Energy (GWh)	Water(Mm³)	Energy (GWh)
Drinking and industrial water	850	550	1,550	2,350
Irrigation	4,400	900	6,500	3,880
Sanitation	-	-	650	215
Reuse of wastewater	-	-	300	200
Total	5,250	1,450	9,000	6,145

The main impacts of climate change on the water sector identified in this study can be summed up as follows:

- Increased water demand due to rising temperatures;
- Reduced rainfall over virtually all of Morocco;
- A reduction in exploitable water potential, of around 10 billion m³ per year;
- A decrease in hydropower potential from planned and completed dams, estimated at around 1,500 GWh per year;
- Changes in the available resource: alterations to river flows and groundwater recharge, degradation of water quality;
- Increased vulnerability of certain ecosystems because of rising temperatures and changes to rainfall distribution in time and space;
- Higher cost of access to water;
- Conflicts over use, etc.

The cost of such impacts, estimated according to the cost of alternative solutions and shortfall in agricultural land equipped for irrigation is set to amount to over 70 billion dirhams.

I. Introduction

Water is something of a rare commodity in Morocco. Renewable natural water resources are estimated at approximately 22 billion m^3 per year, that is approximately 700 m^3 per capita per year, near the threshold of 500 m^3 per capita per year, which is widely recognised as the scarcity threshold that indicates developing scarcity and underlying crises.

As part of its development programme and in order to meet the needs expressed by users, Morocco has been working for some time on managing exploitation of its water resources. Since independence its policy in the face of water shortages and uneven distribution has been to ensure that water supply corresponds to the requirements of towns, cities and agriculture by constructing dams, developing large irrigation areas and setting up systems to supply drinking water to inhabitants. This has led to the creation of reliable infrastructure and competent agencies.

Nevertheless, the Moroccan water sector is facing several limitations and problems which could, if not properly handled, limit the dynamic of economic growth that Morocco is looking for by launching a huge range of large-scale projects.

These limitations and problems relate primarily to decreased water resources due to the impact of climate change which has become a reality in Morocco and whose effects on our environment are already visible.

The future development of water resources depends on solutions characterised by high energy consumption, for example sea water desalination, the reuse of wastewater and the introduction of drip irrigation. Development of the water sector will therefore be closely tied to the development of the energy sector.

This sector must conduct a large-scale programme of studies to understand the current and future impact of climate change, identify and quantify associated costs and its interactions with water and energy and specify adequate solutions for adaptation.

The programme of work on water, energy and climate change in the Mediterranean initiated by Plan Bleu makes a significant contribution to this programme of studies.

This report presents the results of the water, energy and climate change case study in Morocco. It produces an inventory of water resources, water and energy demand and reviews achievements. It also presents strategic opportunities for the development of the water and energy sectors, analyses interaction between water and energy and presents the main impacts of these actions on climate change.

II. Water demand and energy needs for water

1. Resources, water demand and deficit

1.1. Renewable and non-conventional water resource potential

1.1.1. Renewable water resources

Renewable water resources (surface water and groundwater) were estimated at around 29 billion m^3 for an average year on the basis of climatic series from before the 1980s. This estimate was revised down to around 22 billion m^3 taking into account the droughts experienced by Morocco since the 1980s, with a decrease in resources of around 25%.

Water availability dropped to under 600 m^3 per capita per year, which is significantly below the "scarcity threshold" of 1,000 m^3 per year set by the UNDP. It is set to drop below 500 m^3 per capita per year, the "absolute scarcity" threshold, from 2025.

Surface water resources

Surface water inflows reach several millions of cubic metres for the basins with the least water for average years: the Sahara (25 Mm^3), Souss Massa (625 Mm^3), Ziz, Guir, Rheris and Maider (625 Mm^3) basins, and billions of cubic metres for those with the most water: Loukkos, Tangiers, Mediterranean coastlines (3,600 Mm^3) and Sebou (5,600 Mm^3).

This runoff is largely due to rapid and powerful floods. They are generally recorded during an average estimated period of 20 to 30 days for the basins in southern Morocco and two to three months for the basins in northern Morocco and the Moulouya River region.

Surface water resources are evaluated at approximately 18 billion m3 for an average year (see table below). These water resources are characterised by high variability - the resources for nine years out of ten or four years out of five are significantly below this average. In a drought year, water inflow can drop to under 30% of this mean value.

Managing the uneven distribution of water resources in time and space has involved the construction of large dam reservoirs for storing the inflow from wet years to be used in dry years and transferring water from regions with surplus water to regions with water shortages in order to encourage balanced economic and social development across the whole of Morocco.

Table 3 - Average surface water runoff per river basin

River basins	Surface area (km^2)	Average surface water runoff (Mm^3/year)
Loukkos, Tangiers and Mediterranean coastlines Loukkos, Tangiers and western Mediterranean coastlines Nekkor	12,800	3,600
Sebou	40,000	5,600
Moulouya, Figuig, Kert, Isly and Kiss	76,664	1,610
Bou Regreg and Chawia	20,470	847
Oum Er Rbia and El Jadida-Safi	48,070	3,447
Tensift and Ksob-Igouzoulen	24,800	872
Souss-Massa-Draa Souss-Massa Draa	126,480 27,880 98,600	1,398 626 772
Ziz, Rheris, Guir, Bouâanane and Maider	58,841	626
Sahara	302,725	25
Total	710,850	18,025

Groundwater resources

Potential groundwater resources are estimated at around 4,105 Mm^3 per year (Moroccan National Water Debate report, November 2006), of which 1,017 Mm^3 per year comes from irrigation water returned via surface water in particular.

Table 4 - Potential groundwater resources per basin in Mm^3

Basin	Total renewable resources	Natural renewable resources
Loukkos	441.6	406.3
Sebou	423.4	267.5
Moulouya	1,663.8	1,561.8
Bou Regreg	74.1	74.1
Oum Er Rbia	1,012.6	619.3
Tensift	418.2	167.5
Souss-Massa	244.0	212.8
Guir-Ziz-Rheris	336.3	287.7
Draa	312.6	312.6
Saquiat El Hamra and Oued Eddahab	2.5	2.5
Total	4,929.1	3,912.1

1.1.2. Non-conventional water resources

Non-conventional water resources offer a significant water resource potential in Morocco. They involve reusing wastewater, artificial recharge of groundwater and freshwater production through the desalination of sea water or demineralisation of brackish water. The Moroccan National Water Resources Strategy estimates the volume of water that could be exploited from non-conventional water resources at over one billion cubic metres.

Wastewater potential

Overall, wastewater potential is evaluated at around 485 Mm^3 for 2010 and 700 Mm^3 for 2030, of which approximately 60% is discharged directly into the sea. The table below summarises this water potential per basin for 2010, 2030 and 2050.

Table 5 - Wastewater potential per basin

Basin	2010	2030	2050
LTCM	60	90	90
Moulouya	30	45	50
Sebou	90	120	130
Bouregreg Chawia	150	230	250
Oum Er Rbia	45	55	75
Tensift	55	50	60
Souss Massa – Draa	35	75	75
Ziz-Guir-Rheris	10	20	20
Sahara	10	15	15
Total	485	700	765

Sea water desalination

Desalination has overcome technological difficulties and is now a viable, economically competitive and technologically achievable alternative for drinking water or agriculture and the irrigation of some profitable crops. The reverse osmosis technique now used involves passing sea water at a pressure of 70 bars through a special membrane to produce freshwater. This technique has made a significant contribution to reducing operational costs, such that it has been adopted by a large number of countries as the method of choice.

- Desalination is now technically feasible. It provides a reliable resource that can be assessed in advance, making it possible to plan investments and construction projects better;
- Desalination facilities can be built using a BOOT (Build, Own, Operate and Transfer) system;
- Desalination facilities can be built quickly (12 to 24 months including the design stage).

Spain, for example, is already producing 1.5 million m^3 per day and has a number of rapidly growing programmes in both the private and public sectors, and in public-private partnerships.

Morocco is only just starting to produce freshwater by desalination or demineralisation. For the moment, it is only used for urban areas water supply in the Saharan provinces (El Aaiun, Tarfaya, Smara and Boujdour). Overall production capacity is already around 16,500 m^3 per day.

Sea water desalination may be the most appropriate solution to the situation faced by many regions in Morocco to plug the gap between water demand and supply.

The national strategy estimates the contribution of sea water desalination at approximately 400 Mm^3 by 2030.

Brackish water

In Morocco, around a quarter of groundwater is, either in whole or in part, brackish water. This water is mostly situated in the country's desert and semi-desert regions.

Exploitation of brackish water resources began in 1970. Around ten small brackish water demineralisation plants with a total production capacity of over 480 m^3 per day were installed with the aim of producing drinking water. This demineralised water production capacity is now 4,360 m^3 per day with the construction of plants in the cities of Tarfaya, Smara and Tan-Tan.

1.2. Current use of water resources

Since the 1960s, Morocco has adopted an appropriate policy of water resources development focussed on the construction of dams which has provided drinking water supply security for all the towns and cities in the country and made it possible to develop approximately 1,500,000 ha of irrigated land, of which approximately 700,000 ha are part of large irrigated areas.

This supply policy means water infrastructure of 145 large dams (17 under construction), a storage capacity of 17.5 billion m^3, 13 water transfer structures and large structures for abstracting groundwater are now available.

This water infrastructure has been designed and built in order to provide an overall volume in the region of 13 billion m^3 in a year with average rainfall year.

This infrastructure provides significant benefits to the Moroccan economy. This can be seen in the strategic role of the contribution of the sectors associated with dams to the country's water and food security, the growth in farmers' incomes, employment, the opening up of different regions and access to various public services (drinking water, electricity, etc.)

Table 6 - Economic benefits of water resource management (2008)[1]

Hydropower	Installed capacity (MW)		1,729
	Average hydroelectricity production (GWh per year)		1,200
Access to drinking water	Urban environment		100
	Rural environment		90
	Contribution of dams to drinking water network (AEP)	Proportion of total population (%)	33
		Proportion of urban population (%)	65
Agricultural development	Surface area equipped for irrigation (ha)		1,500,000
	Agri-food industry development	Sugar refinery capacity (tonnes)	600,000
		Dairy capacity (million litres)	500
		Canning plant capacity (tonnes)	260,000
		Agricultural GDP (Billions of Dirhams current)	56.7
		GDP (Billions of Dirhams current)	342

Source: ONEP, ONE and Ministry of Agriculture documents

1.2.1. Drinking water

Over the last three decades, the Moroccan Government has operated an ambitious policy of securing drinking water supply to all in towns and cities, reaching a coverage rate of 95% in rural environments.

The drinking water production capacity for urban areas multiplied by 5 between 1972 and 2006, reaching 54.6 m^3 per second. In 2006, total drinking water production exceeded 800 Mm^3 per year, approximately 50% of the volume of water allocated for the drinking water sector.

Everyone has access to drinking water in urban areas. The urban population served now exceeds 17 million inhabitants, 92% of whom are supplied by individual connections. Semi-urban suburbs are supplied by standpipes.

The achievements of the drinking water grouped supply programme for rural environments, launched in 1995, has increased the drinking water access rate, which was under 14% in 1994, to 40% in 2000, 61% in 2004, 77% in 2006 and 85% in late 2008. The table below summarises the progress made in the urban drinking water sector.

Table 7 - Urban drinking water sector indicators[2]

Description	1975	1985	1995	2000	2006
Production capacity (m^3 per second)	11	35	45	50	54.6
Number of people served (millions of inhabitants)	5.3	9.4	13.7	15.1	17.5
Number of people served with individual connection (%)	57	69	81	86	92
Number of people connected to standpipes (%)	26	28	19	14	8

Source: Note ONEP, February 2007

1.2.2. Sanitation and wastewater treatment

The sanitation sector in Morocco lagged significantly behind until 2005, due to the low priority given to wastewater management issues and operator regulation. Over 50% of the population is not connected to an improved sanitation system, 4 million of whom are in urban areas.

As part of the Millennium Development Goal associated with sanitation, Morocco produced a National Programme for Liquid Sanitation and Wastewater Treatment (PNA) in 2005. This programme aims to update the sanitation sector by 2015, with the goal of achieving a connection rate of 80% to the urban sanitation network and reducing urban pollution discharged into the environment by at least 60%.

[1] Source: Documents from the Moroccan National Office for Drinking Water (ONEP), National Electricity Office (ONE) and the Ministry of Agriculture.
[2] Source: ONEP report, February 2007.

The total cost of this programme will be in the region of 43 billion dirhams, and it will affect around 260 towns and cities with a population of around 10 million.

Since its launch, a significant quantitative step has been made in terms of numbers of sanitation and wastewater treatment projects and the volume of investment in this sector. The Government's political will was implemented with increased financial resources allocated to the PNA under the Moroccan Finance Acts, and contributing partners showed a keen interest in this programme and agreed funding and significant assistance to get it launched.

The impact of this programme can be summarised as follows:

- Reduced pollution on the Mediterranean and Atlantic coast, since almost all wastewater from towns and cities discharged into the Mediterranean Sea and the Atlantic Ocean will be treated;
- Almost all wastewater discharged from towns and cities into watercourses will be treated. Treatment of this wastewater and taking into account the environmental aspect in water resource management will lead to an improvement in surface water quality;
- Increasing the water potential which could be used in the development of irrigation. The National Water Resources Strategy, defined in 2009, estimated this potential at approximately 300 Mm^3 per year to be reused in watering golf courses and green spaces as well for irrigation of crops that are suited to it.

1.2.3. Irrigation

In the light of the exploitable water potential, the potential land area for sustained irrigation identified during the 1960s is evaluated at 1.26 million ha which represents approximately 14% of Morocco's total useful agricultural area of 8.7 million ha. In addition, roughly 300,000 ha of land can be irrigated seasonally and by spreading of floodwater.

Currently the land area equipped for irrigation by the authorities exceeds 1 million ha and is distributed as follows:

Table 8 - Land area equipped for irrigation by the authorities in hectares

Area	Land area that could potentially be irrigated	Land area equipped by end 2007
Large-scale hydropower	880,010	682,600
Moulouya	77,280	77,280
Gharb	199,120	113,350
Doukkala	104,600	104,600
Haouz	159,560	142,620
Tadla	109,000	109,000
Tafilalt	27,900	27,900
Ouarzazate	37,650	37,650
Souss-Massa	39,900	39,900
Loukkos	63,000	30,300
Small and medium-scale hydropower	478,090	334,100
Total	1,296,100	1,016,700

In addition to this, the latest studies estimate the total amount of land equipped for irrigation by private developers at over 441,450 ha.

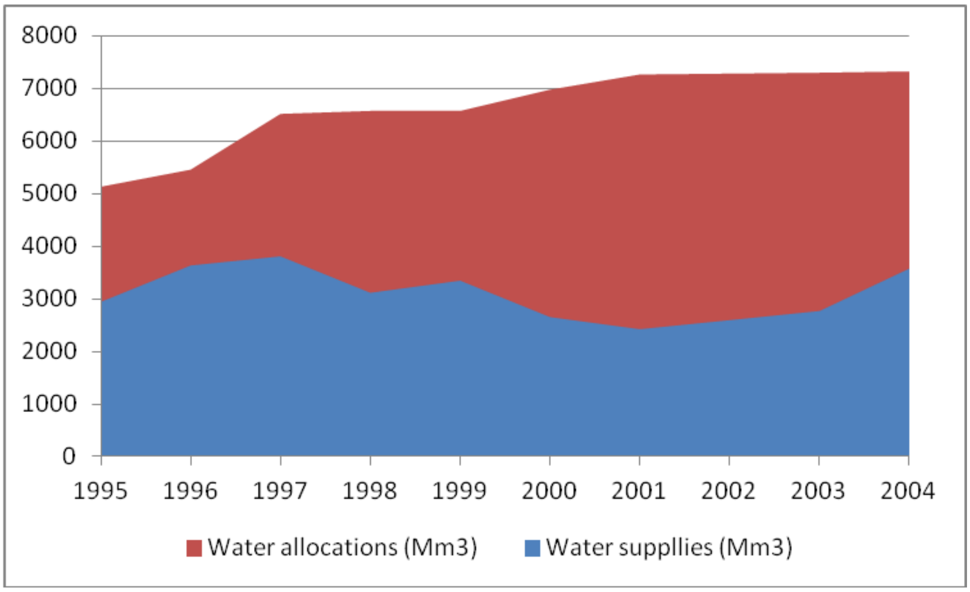
The land area currently irrigated is therefore evaluated at over 1,450,000 ha. 81% of it uses gravity-fed irrigation, 9% uses sprinkler irrigation and 10% uses drip irrigation.

Table 9 - Distribution of irrigated land area by irrigation type in hectares

Irrigation type	Gravity-fed	Sprinkler	Drip	Total	Percentage
Large-scale hydropower dams	533,900	113,800	34,900	682,600	47%
Small and medium-scale hydropower dams	327,200	6,900	-	334,100	23%
Private irrigation	317,600	16,950	106,900	441,450	30%
Total	1,178,700	137,650	141,800	1,458,150	100%

These areas record mean water deficits of approximately 4 billion m³ per year. Water supplied from all dams during the period 1980-2005/2006 for irrigating these areas was evaluated at approximately 2.8 billion m³ per year on average. This supply level was over 50% less than that set out in the PDAIREs. Appendix 1 and the figure below illustrate the size of irrigation water deficits observed across all agricultural areas.

Figure 1 - Water deficits recorded for agricultural areas



This decrease was compensated for by overuse of groundwater. The vast majority of Morocco's aquifers (Souss, the Atlantic Coast, Bahira, Saiss, Haouz, southern oasis) are overused and their levels are several metres down per year, often forcing farmers to abandon their land. The volume of water overused is evaluated at approximately 1,092 Mm³ per year.

This alarming deficit of approximately 4 billion m³ per year, of which approximately 1 billion m³ comes from overuse of groundwater, is the direct consequence of the impact of climate change.

The "Green Morocco Plan" aims to reduce this deficit by increasing the area of land irrigated by water-saving techniques to approximately 700,000 ha.

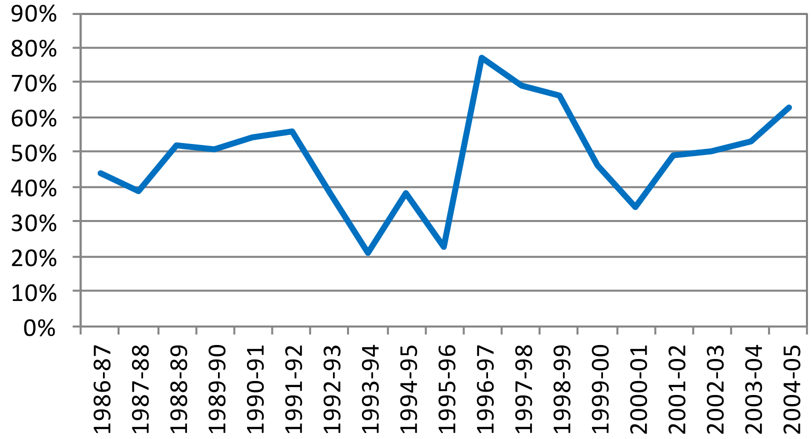
1.2.4. Hydroelectric power generation

Around twenty hydropower plants were built as part of the programme to make use of the water resources made available for exploitation by water infrastructure completed. These plants were planned, designed and substantiated to provide average annual electricity production in the region of 2,600 GWh per year.

The average amount of electricity generated by these plants is evaluated at approximately 1,200 GWh per year, a gap between actual generation and that planned in the PDAIREs in the region of 55%.

These gaps in irrigation water supply and electricity generation are primarily due to the impact of climate change which has led to a decrease in hydroelectric dam heads. Reservoir fill rates measured over recent years have been low (50% down according to a 10-year average). The graph below illustrates these rates for dams observed.

Figure 2 - Fill rates for reservoirs in Morocco (in %)



1.3. Future water demand

Overall, water demand for all use sectors is evaluated at approximately 13.4 and 13.6 billion m³ in 2030 and 2050 respectively, distributed as follows:

Table 10 - Changes to future water demand not taking climate change into account in Mm³

Use sector	2010	2030	2050
Drinking (urban and rural) and industrial water	1,063	1,615	1,850
Not served industry and tourism	212	345	345
Irrigation water	13,225	11,280	11,270
Hydroelectric power	-	-	-
Environmental needs	149	149	149
Total excluding not servedindustry and tourism	14,437	13,044	13,269
Total including isolated industry and tourism	14,649	13,389	13,614

1.3.1. Water demand for the supply of drinking and industrial water

Forecasts for future domestic water use are based on population growth, rural to urban migration and water demand per capita projections.

Overall, drinking, industrial and tourist demand forecasts for the whole of Morocco by 2030 and 2050 are evaluated at 1.96 billion m³ and 2.2 billion m³ respectively.

Drinking and industrial water demand is evaluated at approximately 1 billion m³ for 2010. This demand will reach 1.6 billion m³ and 1.85 billion m³ respectively by 2030 and 2050.

In rural areas, drinking water demand is estimated at approximately 137 million m³ per year for 2010. It is set to reach around 400 million m³ by 2050.

Appendix 2 summarises drinking water demand for urban and rural populations.

1.3.2. Irrigation water demand

Agricultural water demand corresponds to the potential irrigation water needs evaluated on the basis of recommended rotations and theoretical water needs of crops.

This water demand has been evaluated in the PDAIREs at approximately 14.6 billion m³ including approximately 7.8 billion m³ for the areas served by large-scale hydropower dams (including water demand for areas not equipped for irrigation), 3.3 billion m³ for small- and medium-scale hydropower dams and around 3.5 billion m³ for private irrigation.

The launch of the "Green Morocco Plan" alters this demand to 5.967 billion m³ per year for the large-scale hydropower dams, 3.148 billion m³ per year for small- and medium-scale hydropower dams and 2.154 billion m³ for private irrigation (see Table below).

The "Green Morocco Plan" leads to a reduction in agricultural water demand of approximately 3 billion m³. This comes primarily from the introduction of drip irrigation over an area of 700,000 ha and the decision to stop using irrigation equipment in the agricultural zones around Doukkala and Haouz.

Table 11 - Irrigation water needs per basin in Mm³

Basin	Large-scale irrigated areas	Small- and medium-scale irrigated areas	Private irrigation	Total
Moulouya	574	230.3	144.2	948.5
Loukkos	374	188.1	74.2	636.3
Sebou	1,805	650	600	3,055
Bou Regreg	-	47.7	100.0	147.7
Oum Er Rbia	2,444	346	273	3,063
Tensift	70	602.8	245.7	918.5
Souss-Massa-Draa	524	308.1	635.8	1,467.9
Southern Atlas	176	734.3	80.6	990.9
Saquiat El Hamra	-	41	-	41
Total	5,967	3,148	2,153.5	11,268

1.3.3. Environmental needs

In order to protect the environment, plans are in place to ensure that water levels in rivers remain, whenever possible, sufficient to contribute to the conservation and improvement of the environment. The studies for the PDAIREs allocated around 200 Mm³ for the improvement of healthy flows in the Sebou and Moulouya rivers.

1.4. Resources-demand balance

1.4.1. Current balance

The current balance of water supply and demand is analysed by river basin. It involves comparing water resources and demand in order to establish a representative picture of the water situation at a given date. The assumptions taken into account can be summarised as follows:

- Water demand taken into account corresponds to the demand expressed by users, mainly in the drinking water and irrigation sectors;
- The water resource value taken into account in this balance corresponds to the volume of water regulated by the dams and water abstractions made directly from rivers and groundwater, despite the fact that the latter significantly exceeds renewable levels.

Analysis of the river basin water balances suggests the following conclusions:

- The water balance for the Loukkos basin is in surplus. This surplus can be explained primarily by the delay recorded in equipping the agricultural area for irrigation;
- The water balance for the Sebou basin is in surplus due to the delay recorded in installing the third irrigation unit in the Gharb plain and the areas covered by small- and medium-scale hydropower dams completed but not equipped for irrigation;
- The water balance for the Oum Er Rbia basin is currently in water deficit of around 1,200 Mm³;
- The water balances for the other basins are currently in deficit. The deficits are evaluated at 273 Mm³ per year for the Moulouya, 100 Mm³ per year for the Tensift, 160 Mm³ per year for the Souss-Massa-Draa and 65 Mm³ per year for the Ziz-Guir-Rheris basins.

1.4.2. Surface water projection

Volume of water regulated by the dams

The planning studies performed allow for the construction of around sixty dams across all river basins in order to secure supply for Morocco's water needs. The volumes of exploited and exploitable surface water are taken from the Moroccan National Water Debate report (November 2006), the National Water Plan study, studies for the PDAIREs and specific studies performed for dam construction projects.

The planned dams are intended to be built increasingly far away from the place of water use, and their construction is increasingly complex and costly in both technical and economic terms. They will make it possible to exploit additional water in the region of one billion cubic metres, 50% of which will be in the Loukkos, Tangiers and Mediterranean coastline basins. These projects primarily involve increasing irrigation to areas already equipped for irrigation, and will not make any significant difference to water balances. The table below shows the number of dams planned and the volume of water liable to be made exploitable by their construction.

Table 12 - Changes in volumes of exploitable surface water in Mm³

Basin	2010		2030		2050	
	Number. of dams	Exploited volume	Number. of dams	Exploited volume	Number. of dams	Exploited volume
LTCM	10	558	16	1,213	18	1,260
Moulouya	5	718	10	800	11	900
Sebou	10	2,400	20	2,600	20	2,600
Bouregreg Chawia	4	313	7	358	7	358
Oum Er Rbia	12	2,160	22	2,160	22	2,160
Tensift	3	100	8	170	8	170
Souss Massa - Draa	9	385	13	400	13	400
Ziz-Guir-Rheris	1	139	10	774	10	774
Sahara	1	30	1	30	1	30
Total	55	6,803	109	8,505	110	8,652

Exploiting this additional water as a resource would require, according to the National Water Resources Strategy, the construction of 59 dams and a water transfer project from the northern river basins to the Oum Er Rbia and Tensift basins.

Exploiting water courses

In addition to water resources regulated by dams, water is also exploited via direct abstraction from water courses. This type of abstraction has been practiced for an extremely long time and is evaluated at an average of around 1,500 Mm³ per year (see Table 13).

Table 13 - Abstraction from water courses in Mm3 per year

Basin	2010	2030	2050
LTCM	16	16	16
Sebou	600	600	600
Moulouya	350	260	260
Bou Regreg and Chawia	10	10	10
Oum Er Rbia	205	205	205
Tensift	213	160	160
Souss-Massa-Draa	54	54	54
Guir-Ziz-Rheris	-	-	-
Saquiat El Hamra and Oued Eddahab	-	-	-
Total	1,448	1,305	1,305

Groundwater projection

The groundwater projection takes into account the impact of the measures in the National Water Resources Strategy on inflow and outflow. This mainly involves:

- Implementing the irrigation water conservation programme, which will lead to a significant reduction in water abstraction and irrigation returns;
- Use of surface resources to replace groundwater abstraction. A volume of around 90 Mm^3 abstracted for drinking water from groundwater will be replaced by surface water (90 Mm^3 per year by 2020);
- Artificial recharge of groundwater. The National Water Resources Strategy evaluated this recharge at around 280 Mm^3 per year by 2030, with around 100 Mm^3 from treated wastewater;
- Strengthening of the monitoring and sanctions system for over-users and the restriction of pumping from groundwater (revised pricing framework, removal of subsidies providing incentives to overuse, implementation of measures for the setting up of protected and prohibited areas, etc.)

These measures to improve groundwater recharge and especially reduce water abstraction will make it possible to contain demand, set to vary very little between 2010 and 2030, and especially between 2030 and 2050. In these conditions, groundwater balances will slowly even out, mainly by a decrease in outflow by natural outlets.

The groundwater projection takes into account changes in irrigation return water which will be realised by implementation of the National Water Conservation Programme, changes in outflow realised by changes in irrigation return water and the ongoing decrease in groundwater levels, and changes in water abstraction realised by the National Water Conservation Programme and the strengthening of the control system.

1) Evolution of irrigation return water

Table 14 - Evolution of irrigation return water in Mm^3

Basin	2010	2030	2050
LTCM	35.3	32.3	32.7
Sebou	155.9	76.3	77.4
Moulouya	102.0	124.3	126.6
Bou Regreg and Chawia	0.0	0.0	0.0
Oum Er Rbia	393.3	221.9	223.8
Tensift	250.7	208.3	186.0
Souss-Massa	31.2	23.1	18.9
Guir-Ziz-Rheris	48.6	0.0	0.0
Draa		44.9	44.9
Saquiat El Hamra and Oued Eddahab		0.0	0.0
Total	1,017.0	731.1	710.3

The volumes of irrigation return water will be affected by changes in the surface area of irrigated land and irrigation methods. The conversion of traditional irrigation to drip irrigation will significantly reduce irrigation return water volumes. Changes in irrigation return water not taking climate change into account are presented in the following table, by basin.

2) Evolution of outflow

In the same way, outflow by natural outlets will change in accordance with the overall balances and changes in the main terms of the balances, in particular recharge and abstractions.

If we do not take into account the effects of climate change, and in accordance with the assumptions selected which make the variation for inflow and abstractions low, especially between 2030 and 2050, the balances will tend to even out by 2050 via the reduction of outflow from natural outlets.

Table 15 - Evolution of outflow by natural outlets

Basin	2010	2030	2050
LTCM	383.05	344.7	337.9
Sebou	223.1	167.3	133.9
Moulouya	985.4	886.9	798.2
Bou Regreg and Chawia	20.42	11.2	6.7
Oum Er Rbia	544.8	381.4	286.0
Tensift	77.7	23.3	9.3
Souss-Massa	23	6.9	2.8
Guir-Ziz-Rheris	127.83	51.1	25.6
Draa	138.3	96.8	77.4
Saquiat El Hamra and Oued Eddahab	0		
Total	2,523.6	1,969.7	1,677.7

3) Forecast balances

Groundwater forecasts that do not take into account climate change give a water deficit of around 1 billion m^3 that is a water abstraction that exceeds renewable water resources, as shown in the table below.

Table 16 - Forecast balances not taking into account the climate change

Basin	Sustainably exploitable groundwater resources[3]			Groundwater demand			Balance		
	2010	2030	2050	2010	2030	2050	2010	2030	2050
LTCM	58.6	93.9	101.2	63.6	96.8	103.4	-5.0	-3.0	-2.2
Sebou	200.3	230.4	264.9	255.3	264.9	273.6	-55.1	-34.5	-8.7
Moulouya	678.4	745.3	836.3	769.4	802.7	852.4	-91.0	-57.3	-16.1
Bou Regreg and Chawia	53.7	62.9	67.4	106.6	101.2	92.6	-52.9	-38.2	-25.2
Oum Er Rbia	467.8	459.8	557.0	582.8	541.7	563.3	-115.1	-81.9	-6.3
Tensift	340.5	352.5	344.2	552.6	506.3	393.6	-212.1	-153.8	-49.4
Souss-Massa	345.0	353.0	334.0	641.4	508.8	384.0	-296.4	-155.8	-50.0
Guir-Ziz-Rheris	208.5	285.2	310.8	286.4	309.0	317.2	-77.9	-23.8	-6.4
Draa	174.3	215.8	235.2	220.0	232.8	239.3	-45.7	-17.0	-4.1
Saquiat El Hamra and Oued Eddahab	2.5	2.5	2.5	18.9	14.8	5.2	-16.4	-12.3	-2.7
Total	2,529.5	2,801.2	3,053.4	3,497.0	3,378.9	3,224.7	-967.6	-577.7	-171.2

1.4.3. Non-conventional water resources projection

Non-conventional resources primarily consist of artificial groundwater recharge, sea water desalination and treated wastewater. The Moroccan National Strategy for Development of Water Resources gives a significant place to the exploitation of non-conventional water resources. This strategy estimated the

[3] Increasing exploitable groundwater resources will reduce spring flow rates and drainage by water courses.

proportion of this resource at around 910 Mm^3 per year, of which 400 Mm^3 from sea water desalination and around 260 Mm^3 from wastewater.

In 2009, the volume of wastewater is around 500 Mm^3 per year and forecasts set 2030 and 2050 levels at around 700 and 765 Mm^3 respectively. This water potential is intended to be used for watering green spaces and sports fields and developing irrigation around urban areas. Its impact on water balances remains relatively low for the following reasons:

- Wastewater from towns and cities in inland Morocco is already included in the water balances;
- Wastewater from coastal towns and cities are intended to irrigate new agricultural areas.

Desalinated sea water is intended to be used as follows:

- To supply water to coastal towns (Dakhla, El Aaiun, Tiznit, Agadir, Essaouira, Safi, El Jadida, Al Hoceima, Nador, Saidia, etc.) This would secure water supplies for these towns and cities and free up a volume of water in the region of 600 Mm^3 to offset the irrigation water deficit;
- To supply drinking water to the towns and cities of Casablanca, Rabat, Salé and Temara when water resources from the Sidi Mohammed Ben Abdellah dam are saturated. Water resources abstracted from the Oum Er Rbia basin will be left for irrigation in order to offset the water deficit observed in this basin;
- To provide for OCP's water needs, assessed at around 100 Mm^3 in 2020;
- To develop irrigation in the Chtouka area in the Souss - Massa basin by 2030. By 2050, other agricultural areas could be irrigated depending on the lessons learned from the Chtouka experience.

The table below presents the anticipated contribution of desalinated sea water and treated wastewater. It should be noted that the contribution of wastewater has been deliberately limited to the volumes that will affect the water balances. This consists mainly of:

- Wastewater from the cities of Marrakech and Agadir which will be used to water golf courses;
- Wastewater from tourist resorts which will be used to water golf courses and green spaces.

Table 17 - Evolution of volumes of exploitable non-conventional water in Mm^3

Basin	2030		2050	
	Desalination	Wastewater	Desalination	Wastewater
LTCM	5	90	5	90
Moulouya	5	45	5	50
Sebou	-	120	-	130
Bouregreg Chawia	150	230	150	250
Oum Er Rbia	120	55	150	75
Tensift	30	50	35	60
Souss Massa – Draa	150	75	150	75
Ziz-Guir-Rheris	-	20	-	20
Sahara	30	15	40	15
Total	490	700	535	765

1.4.4. Overall forecasts

The overall water balances in the table below were produced for each basin as follows:

- Increased exploitation of non-conventional water resources, mainly via sea water desalination and the reuse of wastewater. These water resources, which will require significant investment, are set to represent around 15% of Morocco’s overall water resources by 2030;

- Water demand controlled via the implementation of the water conservation programme for the drinking and irrigation water sectors;
- Continuing exploitation of the conventional water resources especially in the Loukkos, Tangiers and Mediterranean coastline basins, without taking into account their cost and environmental impact.

The water balances set out in Appendix 8 show that the majority of river basins are in deficit;

- The water balance for the Loukkos, Tangiers and Mediterranean coastline basins is in surplus. Freeing up this surplus volume, evaluated at around 600 Mm³, would require the construction of complex and costly infrastructure (a windowless tunnel of around fifty kilometres);
- The water balance of the Sebou basin, currently in surplus, is set to balance out by 2030 once the large-, medium- and small-scale hydropower dams have been equipped for irrigation, and on completion of the project to protect the Saiss plain.
- The water balance for the Oum Er Rbia basin is set to show a water deficit of around 671 Mm3 by 2030;
- The water balances for the other basins are, and always will be, in deficit. This is the case for the Tensift, Sous Massa – Draa and Guir-Ziz-Rheris basins.

Table 18 - Overall water balance not taking climate change into account in Mm³

Basin	Exploited or exploitable surface water resources			Exploitable groundwater resources			Reuse			Desalination			Drinking water demand		Agricultural water demand		Environmental demand		Export/Import		Balance	
	2010	2030	2050	2010	2030	2050	2010	2030	2050	2010	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
Loukkos	558	1,213	1,260	59	94	101	1	90	90		5	5	189	217	636	636					577	603
Moulouya	718	800	900	200	230	265	9	45	50		5	5	113	130	949	949	32	32			-14	109
Sebou	2,400	2,600	2,600	678	745	836	18	120	130				298	344	3,055	3,055	63	63			49	104
Chawia dam	313	358	358	54	63	67		230	250		150	150	479	531	148	148			-120	-120	294	266
Oum Er Rbia	2,160	2,160	2,160	468	460	557	12	55	75		120	150	180	216	3,063	3,063	54	54	280	280	-782	-671
Tensift	100	170	170	341	353	344	16	50	60		30	35	140	165	919	919			-160	-160	-296	-315
Souss-Draa	385	400	400	345	353	334	2	75	75		150	150	127	148	1,468	1,468					-617	-657
Ziz-Guir-Rheris	139	774	774	174	216	235		20	20				48	55	991	991					-29	-17
Saquiat El Hamra	30	30	30	3	3	3		15	15	7	30	40	37	43	51	41					-10	4
Total	6,803	8,505	8,652	2,322	2,517	2,742	58	700	765	7	490	535	1,615	1,850	11,280	11,270	149	149	0	0	-832	-575

2. Energy needs for water

Electrical energy is used mainly for the operation of pump and injection stations for drinking, industrial and irrigation water, drinking water treatment plants and activated sludge wastewater treatment plants. It is also used for lighting and for pumping in marine outfalls.

Overall, the water sector currently consumes around 1,450 GWh. This consumption is set to rise to 6,150 GWh by 2030 (0.7-0.8 kWh/m³), more than four times current consumption. This predicted increase is mainly due to:

- The use of energy-intensive solutions – e.g. sea water desalination and the water transfer project.
- Use of conventional, high energy-consuming resources in order to meet water demand. This is the case of water pipes for drinking water supplythe cities of Meknes, Tetouan, Fez, Oujda, Marrakech, etc.
- Development of sanitation and wastewater treatment activities.

Table 19 - Evolution of energy consumption in the water sector

Sector	2010		2030	
	Water (Mm³)	Energy (GWh)	Water (Mm³)	Energy (GWh)
Drinking and industrial water	850	550	1,550	2,350
Irrigation	4,400	900	6,500	3,880
Sanitation	-	-	650	215
Wastewater reuse	-	-	300	200
Total	5,250	1,450	9,000	6,145

2.1. Current need

These needs, collected from water users, seem to be in the region of 1,450 GWh, or 0.21 kWh/m³. This consumption is broken down as follows:

- 550 GWh for the drinking water and sanitation sector, about 0.65 kWh/m³ of water produced.
- 900 GWh for the irrigation sector, or about 0.15 kWh/m³:
  - 230 GWh for agricultural areas irrigated from surface water.
  - 650 GWh for agricultural areas irrigated from groundwater. These energy needs have been estimated on the basis of the amount of water abstracted, observed pump performance and heads observed in different aquifers.

Appendix 6 presents the energy consumption of the agricultural water sector and the volume of pumped water.

2.2. Energy needs by 2030

These energy requirements were evaluated on the basis of current needs and the provisions adopted regarding usage of conventional and unconventional water resources, water saving programmes, drinking water generation programmes, sanitation and wastewater reuse programmes, and programmes aimed at water conservation and expansion of irrigation in the Gharb plain.

2.2.1. Drinking water

Energy requirements were estimated on the basis of current needs and drinking water supply projects adopted in connection with planning studies. These energy needs are estimated at around 2,350 GWh, or 1.5 kWh/m³:

- Sea water desalination for the cities of Rabat, Casablanca, Mohammedia, El Jadida, Safi, greater Agadir, Tiznit, Sidi Ifni, Saharan cities and the OCP. These needs are estimated at approximately 1,800 GWh, or 3.7 kWh/m³.
- Use of energy-consuming drinking water supply systems: Meknes from the Idriss I dam, Oujda from Mechra Hommadi, Marrakech from the Oum Er Rbia river.

2.2.2. Sanitation

Electrical energy is used mainly for the operation of activated sludge wastewater treatment plants (in lagoon-based wastewater treatment plants (WWTPs) it is used for pumping and sometimes for treatment), for network pumping and for lighting. It is also used for pumping in marine outfalls.

The electrical energy estimate is based on the following assumptions:

- The activated sludge purification process was adopted for WWTPs serving more than 100,000 inhabitants. The power consumption for these WWTPs was calculated on the basis of 1 kWh/kg BOD5 eliminated.
- The lagoon-based purification process was adopted for all other towns and cities. The power consumption for these WWTPs is negligible. The national sanitation plan has estimated this consumption at around 10% of the consumption of WWTPs that use activated sludge.

On this basis, the national water plan estimated the energy requirements for sanitation and wastewater treatment, presented in the table below.

Table 20 - Evolution of energy requirements (GWh)

	2010	2030	2050
Energy needs	-	215	215

This data does not take into account energy needed for wastewater reuse (additional treatment, pumping water to the place of use, etc.).

2.2.3. Irrigation

Overall, the water needs of the agricultural sector are estimated at around 3,380 GWh per year. The assumptions used in estimating these water needs can be summarised as follows:

- Current energy needs of agricultural areas are estimated at about 900 GWh per year.
- The energy requirements of extensions to agricultural areas, planned for the Gharb plain and the Loukkos river basin, are estimated at about 230 GWh per year.
- Irrigation of the Saiss plain from the Upper Sebou. These needs are estimated at about 150 GWh per year.
- The energy requirements of the Chtouka area, which will include irrigation supplemented by desalinated seawater, would be in the region of 300 GWh per year.
- The energy requirements generated by the transfer of water from the Sebou basin to the Oum Er Rbia are estimated at approximately 1,400 GWh per year, or 2 kWh/m^3 (Appendix 6).

2.2.4. Wastewater reuse

Overall, the energy requirements of wastewater reuse projects are estimated at around 200 GWh, or 0.7 kWh/m^3.

The assumptions used to estimate these needs are:

- Reusing a volume of treated wastewater in the region of 300 Mm^3 per year for watering golf courses and green spaces as well as for irrigation of those crops that are suited to it.
- Development of reuse projects in the coastal zone encompassing Rabat-Casablanca, Marrakech, Agadir, Meknes, Oujda and Fez.

III. Energy demand and water needs for power generation

In the absence of a rigorous energy efficiency policy, energy and electricity demand in Morocco will increase substantially between now and 2030 in order to cope with population growth and economic development, but could be contained if all potential energy savings were realised.

The energy sector's water requirements are high in terms of electricity generation in hydroelectric plants, and as make-up water for cooling in classic thermal power stations, particularly for those located in the country's interior.

In this regard, the present report will look in detail at the energy sector in Morocco and the Moroccan strategy to diversify energy sources. It will then go on to analyse the energy sector's water demand.

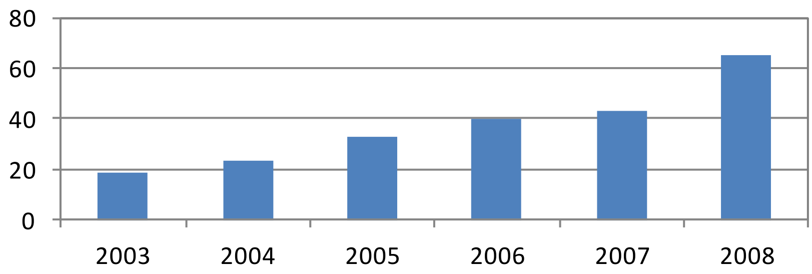
1. National energy context

Morocco currently imports over 97% of its energy supplies due to its own minimal resources.

Such dependence on outside sources, combined with the upward trend of energy prices, particularly oil, which represents nearly 60% of total energy consumption, places a heavy burden on national finances. The energy bill was 50 billion dirhams in 2007 and over 70 billion in 2008, with soaring crude prices, compared to only 21 billion dirhams in 2003, with oil responsible for over 85% of these amounts. To mitigate the impact of escalating prices on consumers and the production sectors, support from the state budget for petroleum products has risen from 700 million dirhams in 2003 to 3.4 billion then 10.7 billion in 2004 and 2007 respectively, exceeding 25 billion dirhams in 2008.

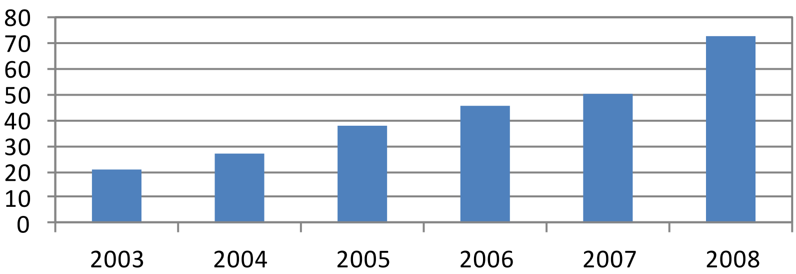
The following graph shows the changes in the oil bill in billions of dirhams.

Figure 3 - Changes in the oil bill in billions of dirhams



The energy bill as a whole has increased by a factor of 3.5 in six years, from 21 billion dirhams in 2003 to 73 billion in 2008.

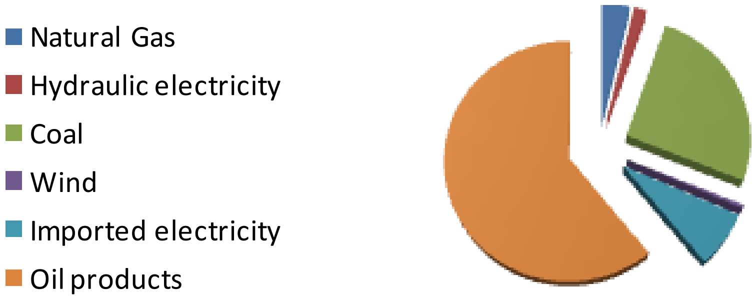
Figure 4 - Evolution of the energy bill in billions of dirhams



Furthermore, consumption of primary energy in Morocco totalled 13.7 million tonnes of oil equivalent (TOE) in 2007, up 5.2% over 2006, driven by a 7.1% increase in power consumption. In the past five years, electricity demand has grown by 8% annually, due to the almost universal access to electricity that has been achieved and to economic growth, which have put a strain on supply. Satisfaction of the demand has thus become structurally dependent on Morocco's interconnections with Spain.

The distribution of energy consumption in 2008, which amounted to 14.72 million tonnes of oil equivalent (MTOE), is represented in the diagram below, by energy source:

Figure 5 - Breakdown of energy consumption in 2008



In the absence of a rigorous energy efficiency policy, by 2030, primary energy demand will be between 35 and 40 MTOE. If all energy saving measures are applied, it should fall within the range of 27-32 MTOE. Meanwhile, electricity consumption, which was 24 TWh in 2007, would rise, taking into account the impacts of energy efficiency actions, to 52 TWh for a low scenario, to 60 TWh for an average reference scenario, or to 70 TWh for a scenario of high economic efficiency.

2. New energy strategy

To meet these multiple challenges and better control Morocco's energy future with a view to ensuring its sustainable development, a new energy strategy was developed based on realistic economic and technological options, as part of a clear vision for the future. It has been broken down into concrete action plans that are achievable in the short, medium and long term, accompanied by organisational and regulatory measures to provide the necessary visibility to operators.

In accordance with the royal directives, the Moroccan Ministry of Energy, Mines, Water and the Environment has identified the strategic options by bringing together national and international experts and all stakeholders in a spirit of consultation, participation and consensus. In this context, the Hassan II Fund for Economic and Social Development has allocated a budget to fund the study of a programme to support priority structural reforms.

The strategic objectives are aimed at securing the energy supply, ensuring availability and accessibility of energy at the lowest possible cost and reducing energy dependence by diversifying energy sources, achieved through developing the national energy potential and promoting energy efficiency in all economic and social activities.

Morocco has thus set itself an achievable energy efficiency potential of 12%, to be reached by 2020, and a share of renewable energy in the national energy balance of between 15% and 20%. By this date, the share of solar, wind and hydroelectric power will represent about 42% of installed capacity (14,580 MW) compared to 26% in 2008 (5,292 MW).

The energy sector's water requirements are high in terms of generating electricity in hydroelectric plants, and as make-up water for cooling in classic thermal power stations. In this regard, we will now take a more detailed look at the energy sector in Morocco.

2.1. Electricity

In Morocco, the forecast for electricity demand is established by the National Electricity Office (ONE), a state-owned industrial and commercial enterprise with nearly 9,000 employees, of which 21% are managers and 48% are supervisors.

In the ONE headquarters in Casablanca, an entire facility is dedicated to planning. Based on the country's energy policy, the ONE matches supply to demand in two steps:

- An initial step to study electricity demand.
- A second step to define an equipment programme in order to satisfy that demand at the lowest possible cost.

Study of the demand

In general, the ONE conducts a detailed analysis of past consumption trends (at national level, by sector, by branch, by voltage level, etc.) to shed light on the different factors that determine demand and assess how they effect it.

1) Retrospective analysis of demand

First, a retrospective analysis of the demand is developed. Generally, a 20-year period is considered for the analysis of overall electricity consumption in order to detect an overall trend and variation in average annual growth. This variation is compared to the average rate of economic growth during the study period, and to population growth.

The analysis is based on:

- A calculation of the elasticity of the electricity demand to GDP.
- A comparison of the population trend index, GDP and electricity consumption over the period studied.
- An analysis of electricity consumption per capita, considered as representing the economic and social dynamics in Morocco.
- An analysis of the characteristics of the electricity demand, overall and by sector.

The ONE finds that the electricity sector has registered a steady increase in demand over the last decade, due mainly to the increasingly widespread electrification of the country, to government urbanisation efforts, to the improvement in household incomes and to the implementation of large-scale infrastructure projects in various regions of the country.

The relevant ONE departments examine the fine detail of changes in demand at peak times and seek to highlight the main reasons for these changes, largely caused by a sharp increase in residential consumption.

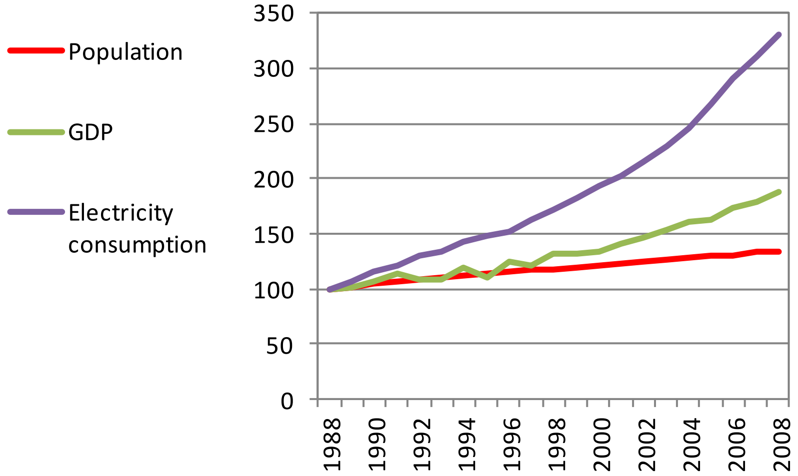
The ONE's electricity sales history is broken down automatically and a customer analysis performed, making a distinction between ONE direct clients and distributors' clients (state distribution companies and concession holders). The impact of the different energy saving campaigns and actions is also considered.

Over the last twenty years (1988-2008), overall electricity consumption has more than tripled, far exceeding economic and population growth.

The elasticity of electricity demand to GDP, estimated over this period, is almost two units. Over a period of two decades, the growth rate of electricity consumption has continuously exceeded GDP and population growth rates, and the difference has become more pronounced since 1998.

For the same period, electricity consumption per capita increased from 275 kWh per capita in 1988 to around 680 kWh per capita in 2008, equivalent to an average annual increase of 4.6%. The graph below traces these developments.

Figure 6 - Change indexes for electricity consumption, GDP and population (baseline of 100: 1988)



Moreover, between 1995 and 2008, electricity demand increased from 10,711 GWh to 24,004 GWh, reflecting an average annual growth rate of approximately 6.4%. Specifically, over the 10-year period between 1998 and 2008, electricity demand saw an average annual growth rate of approximately 7%, as shown in the table below.

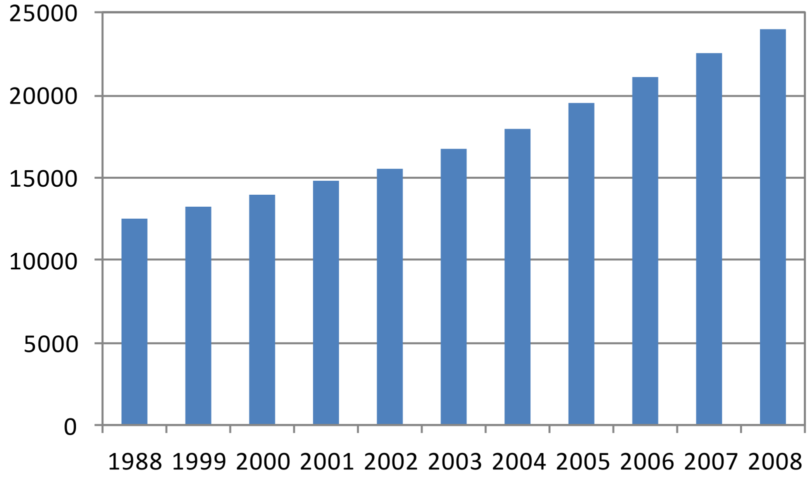
Table 21 - Changes in electricity production by source in GWh

	1995	1996	1997	1998	1999	2000	2001
Coal	5,578	5,753	6,251	7,227	6,927	8,548	11,050
Fuel oil	4,185	3,128	3,200	2,676	3,612	2,183	1,034
Diesel	26	26	29	33	38	40	57
Natural gas							
Hydroelectricity	605	1,938	2,062	1,759	817	705	862
Wind	0	0	0	0	0	64	206
Pumped storage power							
Interconnections	243	128	123	716	1,846	2,363	1,564
Third-party contributions	74	80	104	42	27	39	75
Pumped storage pumping							
Aux. & Compensators							-45
Net energy demand	11,711	11,053	11,769	12,453	13,266	13,942	14,804

	2002	2003	2004	2005	2006	2007	2008
Coal	11,518	11,751	12,519	12,731	12,902	12,457	11,662
Fuel Oil	1,524	1,929	2,061	2,766	2,595	2,758	4,115
Diesel	25	16	4	40	45	3	4
Natural gas				2,003	2,512	2,823	2,867
Hydroelectricity	842	1,441	1,591	965	983	902	916
Wind	194	203	199	206	183	279	298
Pumped storage power			10	447	603	416	444
Interconnections	1,392	1,438	1,535	814	2,027	3,507	4,261
Third-party contributions	84	45	76	86	40	33	40
Pumped storage pumping			-10	-496	-728	-529	-574
Aux. & Compensators	-41	-43	-38	-43	-56	-40	-30
Net energy demand	15,540	16,779	17,946	19,518	21,105	22,608	24,004

The graph below shows two different periods of growth. The difference can be explained by the effects of the electrification of rural areas, overall progress in urbanisation, improvements in household equipment and the momentum built by the large number of projects carried out by Morocco in various economic sectors.

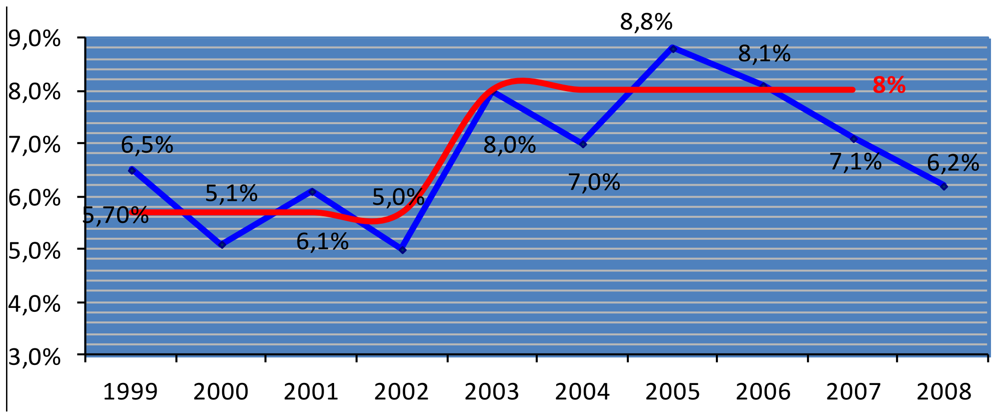
Figure 7 - Changes in consumption in GWh



It should be noted that this growth has been uneven, however, as illustrated in the graph below: moderate growth between 1999 and 2002, followed by a period of burgeoning demand for electricity from 2003 to 2007, with an annual average of 8% reflecting the economic and social dynamism experienced by Morocco, in particular in terms of increased access to basic infrastructure; followed by a drop in consumption in 2008 when growth reached only 6.2%.

The peak maximum power demand increased from 1,393 MW in 1988 to 2,395 MW in 1998 and 4,180 MW by 2008. This represents an average annual growth rate of 5.3% over the first 10 years (1988-1998) and 6.1% for the second period (1998-2008). In 20 years, the peak maximum power demand has thus experienced an average annual growth rate of 5.7%.

Figure 8 - Electricity demand growth rate trend



The declining rate of increase in demand in 2008 can be attributed to a drop in activities in the phosphate and steel industries, which recorded a 7.4% decrease in consumption compared with 2007. Total consumption by EHV-HV corporate account clients was only 2.6% in 2008 compared to an average of 10% during 2003-2007.

In addition, it should be noted that the use of energy-saving lamps was the reason for the decline in consumption by low voltage clients in 2008, which was only 9.4% compared to an 11.6% average between 2003 and 2007. Indeed, the cumulative number of energy-saving lamps installed was 1.845 million in late 2008 and 2.6 million by the end of March 2009. The energy savings expected by the end of 2009 are estimated at 300 GWh, corresponding to 1.2% of net energy demand.

2) Projected electricity demand

Projections of demand are established over long periods and revised for short- and medium-term periods.

For the short term, demand forecasts are automatically revised to reflect the needs expressed by the different client segments, whether direct clients or those of public or private distributors.

For the medium and long term, forecasts of changes in electricity consumption reflect a combination of various types of factor relating to economic activity, demographics, user behaviour, technical progress, development of new uses of electricity, the relative market shares of energy and energy conservation.

Planning to incorporate these factors into long-term forecasts is based on a detailed breakdown of electricity consumption into segments, performed as follows:

- An initial distinction between the industrial, service and residential sectors in total consumption;
- Within these areas, further divisions are made, by branch of economic activity (agriculture, manufacturing, etc.) and by use;
- For each branch or use, characteristic technical-economic variables are identified in order to calculate energy consumption (ownership rates, unit consumption of appliances, number of households, neighbourhood, etc.).

From this detailed segmentation analysis, the choice of assumptions about changes in characteristic descriptive variables can be used to predict consumption for each branch or use. The consumption forecasts thus obtained for the different segments are then aggregated to arrive at forecasts for each sector.

To guard against the growing uncertainties about changes in the energy and socio-economic environment, three macroeconomic scenarios are considered, selected on the basis of the report from the Moroccan High Commission for Planning, entitled *Croissance économique et développement humain; Eléments pour une planification stratégique 2007-2015* ("Economic growth and human development: Elements for strategic planning 2007-2015").

By 2015

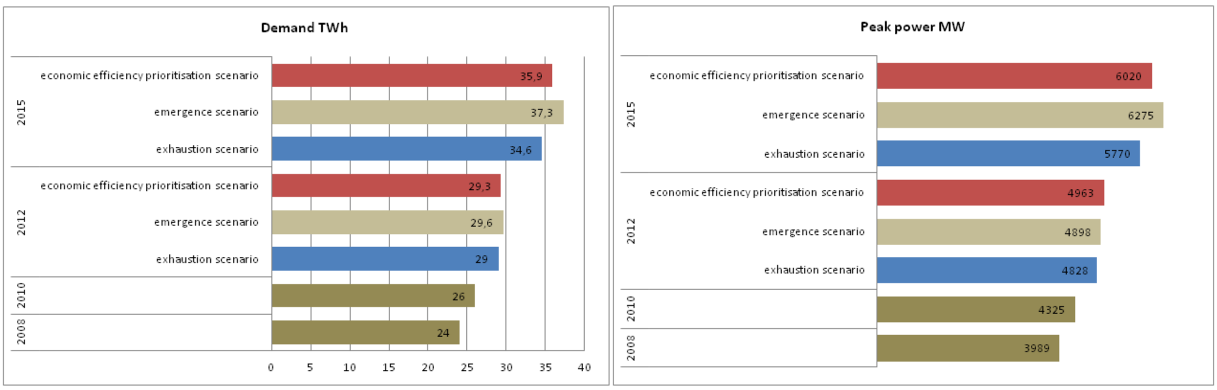
The "emergence scenario" was adopted as a baseline for developing the equipment plan. This scenario predicts a 7% increase between 2011 and 2015, leading to a net energy demand of 35.9 TWh by 2015. In this scenario, growth is driven mainly by the development of services and tourism in the service sector, and by construction in the secondary sector. Growth in the residential sector is also extremely strong as a result of demographics, urbanisation and especially, the development of new specific uses.

The "economic efficiency prioritisation scenario" involves an 8% growth rate of net energy demand between 2011 and 2015, resulting in a net energy demand of 37.3 TWh by 2015.

The "exhaustion scenario" predicts a 6% energy increase between 2011 and 2015, limiting consumption to 34.6 TWh in 2015.

Based on these assumptions, projections of demand for electrical energy and peak power, resulting from the three macroeconomic scenarios described above, are as follows:

Figure 9 - Projections of demand for electrical energy and peak power



By 2020

A "segmentation" study, through the identification and consideration of different factors explaining the changes in electricity demand, conducted by Sofreco consultants as part of a study entitled *Intégration progressive des marchés de l'électricité de l'Algérie, du Maroc et de la Tunisie dans le cadre du marché intérieur de l'électricité de l'union Européenne* ("Gradual integration of the Algerian, Moroccan and Tunisian electricity markets in the European Union's internal electricity market") analyses the economic and social contexts that prevailed during the past period and plausible future changes for Morocco, in the light of its potential but also regional and international opportunities and constraints.

The study was set in the context of the scenarios mentioned above. Each of these identifies a plausible situation that could describe possible future electricity consumption trends.

These three scenarios were constructed based on the determining factors considered as explanatory of the electricity consumption of the different sectors.

Thus, the emergence scenario is characterised by 6% annual growth between 2015 and 2020; the economic efficiency prioritisation scenario would involve an annual growth rate of net energy demand in the region of 7.2%; the exhaustion scenario would see an average annual increase of 5.2%.

By 2030

It is assumed that by 2030 a form of saturation will have occurred in a number of sectors of economic activity, that consumption in the residential sector will have stabilised and that tangible effects of the energy efficiency policy will be felt throughout the country.

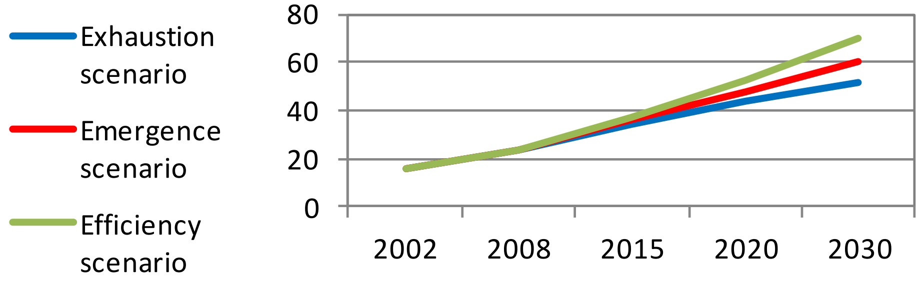
At this point, then, the emergence scenario would be limited to growth of 4.2% per year; the economic efficiency prioritisation scenario, 5.5% per year and the exhaustion scenario would not exceed an average annual rate of 3.5%.

The growth in consumption at the various dates quoted above is summarised in the following table:

Table 22 - Projected electricity demand in TWh

Date	2002	2008	2015	2020	2030
Exhaustion scenario	15.5	24	34.6	44	52
Emergence scenario	15.5	24	35.9	48	60
Efficiency scenario	15.5	24	37.3	53	70

Figure 10 - Projected electricity demand in TWh



Study of the supply

The aim is to develop a production facilities equipment programme in order to meet, at minimum cost and according to predefined quality and continuity of service criteria, changes in demand.

The development of the equipment programme takes account of:

- The continued development of national primary energy resources
- The diversification of external fuel supply sources

- The quest for greater energy efficiency

It is determined by minimising the sum of the following discounted costs:

- Investment costs
- Operation and maintenance costs
- Fuel costs
- Cost of energy not served

It takes into account a number of constraints and criteria, including:

- Satisfaction of priority irrigation and drinking water needs
- Satisfaction of energy demand
- Monitoring fluctuations in power demand (load curve)
- Planned and unplanned outages
- The reserve margin

3) The Electric Power Supply

In late 2008, the total installed capacity of the generating facilities was estimated at 5,292 MW and consisted of Independent Power Producers (IPPs) as well as facilities directly under the ONE. The existing national facilities[4] on that date are detailed below.

Independent Power Producers

- Jorf Lasfar power station (1,320 MW): Developed as an IPP with purchase guarantee, this four-generator power plant (4x330 MW) operates with imported coal.
- Tahaddart combined-cycle power plant (380 MW): The Tahaddart plant is the first in Morocco to use combined-cycle technology powered by natural gas. This plant has total guaranteed net power of around 380 MW. Its natural gas supply is provided by the Maghreb-Europe gas pipeline, through a 13 km feeder line.
- Abdelkhalek Torres wind farm (54 MW): Located in the area between Tangiers and Tetouan, this wind farm has a total installed capacity of approximately 50 MW, with mean energy production capacity of around 200 GWh per year.

ONE Facilities

- Steam plants (1,065 MW): The three steam plants have a total installed capacity of 1065 MW, of which 600 MW is at Mohammedia (4x150 MW, including two burning fuel oil and two coal), 300 MW at Kenitra (4x75 MW burning fuel oil) and 165 MW at Jerada (3x55 MW fuelled by coal mixed with petcoke). These power stations are used to meet additional basic energy needs, after the Jorf Lasfar and Tahaddart plants.
- Gas turbines (615 MW): The gas turbine facilities consist of 20 MW and 33 MW units spread over the entire Moroccan territory, totalling an installed capacity of 615 MW, fuelled by oil. These units are used mainly to cover peak demand and relief to the national grid, in the event of a major incident affecting production facilities.
- Diesel generators (69 MW): Spread over several regions, diesel generators have an installed capacity of about 69 MW.
- Amougdoul–Essaouira wind farm (60 MW): Located in Cap Sim, 15 km to the south of the city of Essaouira. It has 71 wind turbines with a total capacity of 60 MW.

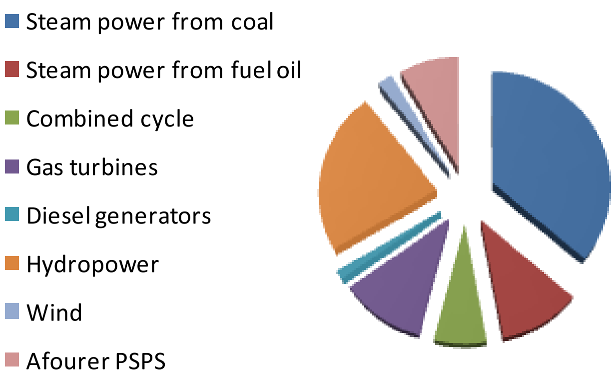
[4] All power stations under the ONE, whether managed directly or as Independent Power Producers; autonomous production facilities are not included as part of the national stock.

- Afourer Pumped Storage Power Station (464 MW): Pumped Storage Power Stations transfer and store energy at off-peak times, by pumping water from a lower to a higher reservoir, and then running it through turbines to produce electricity at peak times. This facility, with an installed capacity of 464 MW, contributes to the optimisation of the production cost and the operational flexibility of the electrical system.
- Hydroelectric facilities (1,265 MW): The hydropower facilities consist of 26 hydroelectric plants with a total installed capacity of 1,265 MW, combined with multi-purpose hydro projects. The electricity production from these facilities is dependent on hydrological conditions and irrigation and drinking water needs.

Table 23 - Breakdown of electricity generation facilities in 2008

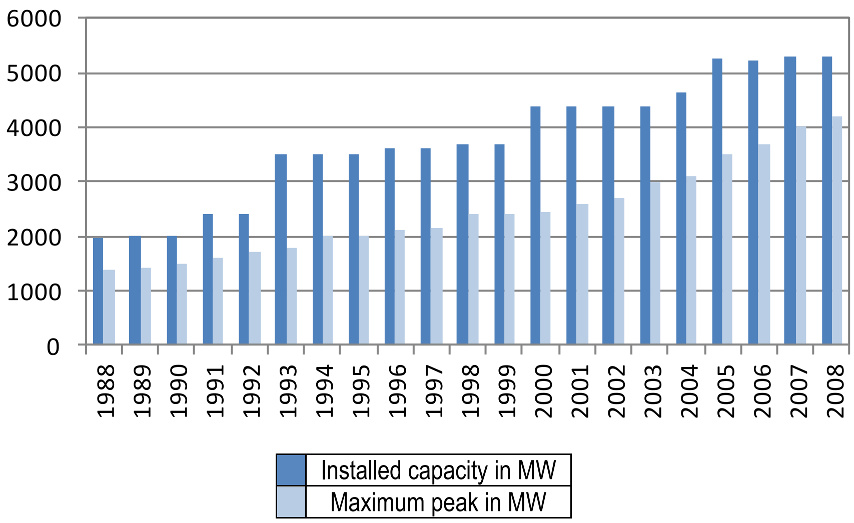
Type of production facility	Installed capacity in MW	Percentage share
Steam power from coal	1,785	33.7
Steam power from fuel oil	600	11.3
Combined-cycle	380	7.2
Gas turbines	615	11.6
Diesel generators	69	1.3
Hydropower	1,265	23.9
Wind	114	2.2
Afourer PSPS	464	8.8
Total	5,292	100

Figure 11 - Breakdown of installed capacity in 2008 (MW)



The installed capacity increased from 1,971 MW in 1988 to 3,683 MW in 1998, peaking at 5,292 MW in 2008. This resulted in an average increase in capacity of 190 MW per year between 1988 and 1998, and of around 180 MW per year between 1998 and 2008. The additional capacity changes in increments that are easier to view in the graph below.

Figure 12 - Changes in installed capacity and maximum peak power demand



2.1.1. New electricity strategy

The Moroccan power sector is facing many challenges related to security of supply, diversification of energy sources, organisational and legal aspects as well as strategic planning.

For this reason and in accordance with the country's royal directives, the Ministry of Energy, Mines, Water and the Environment named the electricity sector as one of its major concerns to be addressed as part of a vision for the future, the aim being to set as a priority, the adoption of an electricity policy that will generate action plans designed on the basis of a clear vision for reform. These plans are broken down into concrete measures and feasible projects. The overall aim is to ensure a competitive power supply in the service of the national economy at all times.

The Ministry of Energy, Mines, Water and the Environment has involved a broad range of national and international experts along with all stakeholders, to develop documented, widely-shared visions of four elements that constitute the foundations of the national power strategy:

- Changes in domestic demand, and potential major discontinuities.
- The advantages and constraints specific to Morocco.
- The economic and technical characteristics of the available power generation technologies.
- Changes in the costs of different fuels (coal, gas, uranium, etc.).

<u>Basic principles for choosing an electricity mix</u>

1) Economic fundamentals of the electricity sector
    - ♦ The fundamental importance of access to reasonably-priced electricity for economic and social development.
    - ♦ Focus on the full costs, from a national, long-term planning perspective.
2) Order of economic merit of production technologies

    Comparing the cost structures of the different technologies and positioning them according to the order of merit for long-term planning (ignoring the Kyoto effect, not applicable in Morocco).
3) Portfolio approach to defining the electricity mix

    Four criteria for defining the mix:
    - ♦ Economic criterion: Satisfaction of demand, including safety margin, at the lowest overall cost.
    - ♦ Strategic criterion: Security of supply in terms of volume and price.
    - ♦ Environmental criterion: Sustainable development and commitment with regard to environmental risks.
    - ♦ Political criterion: Choice of the degree of dependence and of the countries with which a dependency relationship is established.

<u>Key issues and structural advantages in terms of electricity supply</u>

1) Issues
    - ♦ Morocco's structural dependence on imports of fuels used for electricity (93%).
    - ♦ Difficulty in obtaining sites for power plants because of intense competition with the tourism sector.
2) Advantages
    - ♦ Morocco's non-ratification of Appendix I of the Kyoto Protocol
    - ♦ Significant renewable energy resources and presence of exploratory primary sources (shale-uranium) for medium/long-term exploitation.
    - ♦ Geographical positioning between a major electricity and gas market (Spain and Algeria, respectively).

New Opportunities

1) Significant wind resources

- A wind power potential of 6,000 MW at the sites studied (1.5 times peak demand), estimated at around 25,000 MW across Morocco.
- Extensive distribution throughout the country, for supplying remote, off-the-grid areas.

2) Considerable solar resources

- With more than 3000 hr per year of sunshine, equivalent to radiation of about 5 kWh/m² per year, Morocco has a high solar capacity (average equivalent to Southern Europe).
- Especially high potential in underserved areas in terms of grid and and power production capacity.
- Particularly attractive cost (9% below the reference cost).

3) Oil shale: Morocco has the fourth largest reserves of this resource worldwide.

- Considerable proven reserves, but still limited investigation of its potential as fuel for electricity generation.
- Relatively mediocre heating value of Moroccan shale (best at Timahdit) because of its low oil concentration and high humidity. Nevertheless outcrops are near the coast, where extraction and transport costs are relatively low.

4) Geographical positioning between two major markets: attractive arbitrage opportunity for Morocco.

Development of a pragmatic and economically viable portfolio: key points

- Baseline scenario: Coal as the first-choice technology and optimisation of available gas resources.
- Alternative scenarios: Development of gas as a more important basic energy source in the event of affordable, safe access to the raw material.
- Development of wind power on a market basis.
- Organisation of interconnections between Spain and Algeria, accounting for 20% of installed capacity.
- Optimisation of hydroelectric resources.
- Oil shale programme. Arbitrage by 2013 (monitoring, centre of excellence, feasibility 2025).
- Development of a targeted solar programme.
- Investigation of the biomass potential.
- Prolongation of the electricity consumption optimisation programme.
- Launch of three energy efficiency initiatives at national level.

2.1.2. Meeting demand for 2009-2016

To meet the demand for electricity, the ONE has scheduled the completion of the works listed below:

Aîn Beni Mathar solar thermal plant (ABM)

The project is located in Ain Beni Mathar, 86 km south of the city of Oujda, covering a total area of 160 ha including the solar cell array, two gas turbines, two recovery boilers, steam turbine, evaporation pond for discharge water, 225 kV power outlet, 60/6.6 kV emergency station and ancillary rooms.

The parabolic trough concentrator array covers an area of 183,000 m². The combined cycle will operate on natural gas, supplied through the Maghreb-Europe pipeline (GME), and thermal energy from the solar array.

The net power is 472 MW, with the solar share accounting for 20 MW. The annual energy yield is 3,540 GWh, 40 GWh of which is from solar energy.

Gas turbines at Mohammedia and diesel generators at Tan-Tan

These gas turbines and diesel generators have a combined capacity of 416 MW (116 MW from the Tan-Tan diesel generators and 3x100 MW from the Mohammedia gas turbines).

Agadir diesel generators

Four 18 MW diesel generators.

Dakhla diesel generator

One 16 MW diesel generator.

Kenitra gas turbines

Gas turbines with a total capacity of 300 MW.

Extension to the Jorf Lasfar power station

Two coal-fired units (numbers 5 and 6), each with a gross capacity of approximately 350 MW.

Safi coal power station

Coal-fired power station, with a total capacity of 1,320 MW.

Tanafnit - El Borj Hydroelectric Complex

The site of this complex is located near the Oum Er Rbia springs, in Khenifra Province, 40 km northeast of the city. The installed capacity of this complex is 40 MW, with an average annual energy yield of 210 GWh.

Abdelmoumen Pumped-Storage Power Station

The Abdelmoumen dam development site is able to support a pumped storage plant with a capacity of 300 MW. The expected yields of the project are:

- Annual turbine production: 560 GWh
- Annual pump consumption: 720 GWh
- Cycle efficiency: 0.76.

MDEZ and EL MENZEL Hydroelectric Project

The hydroelectric head at M'DEZ and El MENZEL is one aspect of the Upper Sebou development project, which is itself part of the Sebou-Inaouene-Ouergha development plan, designed to meet the region's irrigation, drinking water and energy needs. The total installed capacity is estimated at 200 MW.

Tangiers wind farm

This wind farm, with a capacity of 140 MW, is composed of wind turbines with a rated output of 850 kW per unit. The installed capacity of the farm is divided between the two sites of Dhar Saadane and Beni Mejmel, located 22 km to the south-east of Tangiers and 12 km to the east of Tangiers.

Tarfaya wind farm

The Tarfaya wind farm is located in the Addwikhia region, 2 km south of the city of Tarfaya on the Atlantic coast, along the road from Tarfaya to El Aaiun. This project consists of a 300 MW wind farm, to be developed by a private operator under a 20-year guaranteed purchase contract.

Wind farms as part of the EnergiPro service offering

As part of the government's strategy of encouraging and promoting renewable energy to account for 20% of the electricity balance by 2012, the ONE launched an initiative known as the "1000 MW Wind Power Initiative" to develop 1,000 MW of wind power capacity by 2012, with the aim of strengthening power generation capacity while exploiting Morocco's wind energy potential.

To facilitate the implementation of this initiative, while allowing corporate account clients to participate in renewable energy production, the ONE has also set up an "EnergiPro" service, which gives large industries the opportunity to develop and finance, for their own consumption needs, electricity production projects using renewable energy.

As part of this service, and in accordance with the regulations in this field (Moroccan Act 16-08), the ONE is committed both to ensuring the transport of electricity from production site to consumption site, in exchange for transit fees, and to buying surplus electricity that is not consumed by self-producers.

Projects to renovate existing production facilities

To ensure reliable production facilities, the ONE has launched several renovation projects, with particular focus on the Mohammedia coal-fired plants, gas turbine facilities, the Jerada power station units and existing hydro structures.

Management of hydroelectric facilities

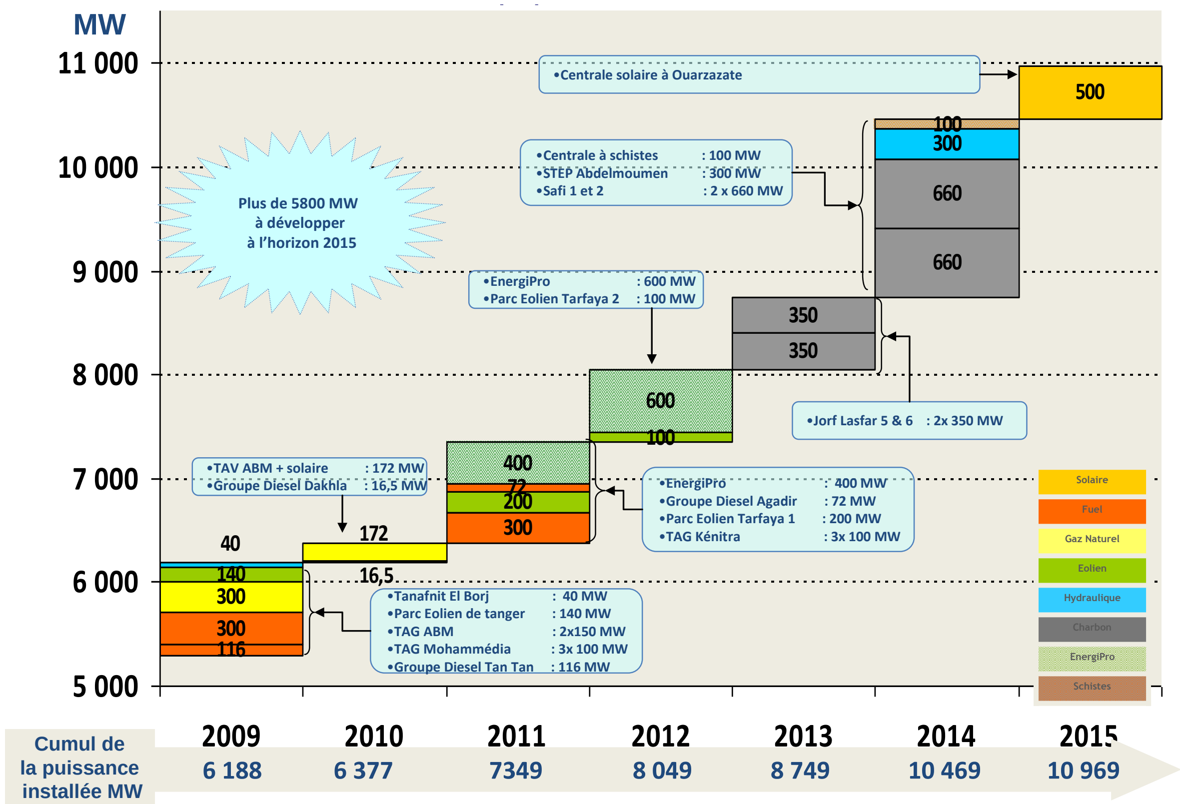
The ONE has undertaken a number of actions, in coordination with the Directorate General for Hydraulic Engineering and water agencies, focused on equipping new hydroelectric facilities and managing existing ones in order to:

- Ensure better coordination between different water users, so as to optimise the placement of hydroelectric power plants during peak hours, without disadvantaging other users.
- Redesign the forebays and compensating tanks, to improve the placement of hydroelectric power plants by giving them more autonomy.
- Promote technologies to improve the efficiency of water abstraction.

Demand-Side Management

Satisfaction of the short- and medium-term energy demand will also be consolidated by actions designed to control energy consumption (demand-side management, DSM) and improve the industrial performance of facilities. It is in this context that initiatives have been proposed to encourage optimisation of consumption, such as GMT+1, promoting the use of more efficient public lighting equipment, rationalisation of electricity consumption, systematic maintenance of facilities, energy audits, distribution of energy-saving lamps with easy payment terms, introduction of a super-peak tariff for EHV-HV clients, which aims to encourage corporate account clients using very high and high voltage supplies to draw less during times of high power demand. All these initiatives, which were the subject of a programme contract in 2008, aim to mitigate the short-term deficit and improve the reserve margin for the stages where it is below 10%, given that the peak capacity threshold is estimated at 540 MW.

Figure 13 - Equipment plan 2009-2016



2.1.3. Meeting demand beyond 2016

Beyond 2016, the various power generation options will be investigated and the necessary means decided in due course, whether wind farms, solar, coal- or natural gas-based plants or hydroelectric projects.

For wind power, the authorities will continue to initiate projects to produce this type of clean energy, while ensuring that their rate of integration into the grid is upheld.

With regard to solar power, Morocco is committed to participating in the Mediterranean Solar Plan, as part of the Union for the Mediterranean, which involves a number of large-scale projects. Within this framework, an integrated project to produce electricity from solar energy, called the "Moroccan Solar Energy Project", was launched in November 2009 by the country's authorities. This project is part of the energy strategy, which gives priority to developing renewable energy and sustainable development. It seeks to establish a total production capacity of 2000 MW by 2020, at five sites: Ouarzazate, Ain Beni Mathar, Foum Al Oued, Boujdour and Sebkhat Tah. This figure is equivalent to 38% of the total installed capacity for late 2008 and 14% of projected capacity by 2020.

This is a massive initiative with an estimated investment cost of US$ 9 billion. The project contributes substantially to reducing the country's energy dependency and energy bill, as well as CO2 emissions, to ensure sustainable economic and social development.

In terms of natural gas, the Moroccan authorities are considering all opportunities for developing its use, whether by exploiting the royalty gas it receives by way of a transit fee from the Maghreb-Europe Gas Pipeline, or the option of a Gas Terminal or a dyke in Tangiers.

The nuclear option has not been written off and there is a good argument for it, given that Morocco imports almost all its primary energy requirements (coal, oil and natural gas) and the cost of the energy bill is constantly on the rise. The Moroccan authorities are looking at updating the feasibility studies, which are over twenty years old, integrating current economic data and developments in the type of nuclear reactor technology that would be compatible with the size of the Moroccan power grid.

In addition, given Morocco's considerable oil shale reserves, there are plans to build an oil shale-fuelled power station with a capacity of approximately 100 MW. The site chosen for the plant, covering an area of about 12 ha, is located beside the ocean, about 38 km east of the city of Tarfaya. It will be built by a specific-purpose company, for private electricity generation.

2.2. Renewable energy

By 2012, renewable energy should make up about 10% of the energy balance and 20% of electrical energy demand, following the commissioning of new power plants predicted to produce 1,440 MW from wind power and 400 MW from hydropower, and the installation of 400,000 m² of new solar panels.

By 2020-2030 all achievable wind potential, estimated at 7,000 MW, could be exploited, depending on site qualification and incentives granted. By 2020, solar power will have been developed by making solar water heaters more widely available, extending the total area covered by solar panels to 1,700,000 m², and increasing the production of photovoltaics (PV) and concentrating solar power plants to 1,080 MW and 400 MW respectively. The installed hydropower capacity will be increased from its current 1,730 MW to 2,700 MW by building new dams and pumped-storage power stations.

2.2.1. Introduction

The development of renewable energy is a major component of Morocco's new energy strategy, aimed at securing supply, ensuring availability and reducing the nation's energy dependence.

Morocco has great renewable energy potential. Exploiting it will cover a substantial part of its growing energy needs and help protect the environment by replacing fossil fuels.

The contribution of renewables to the energy mix will expand gradually, as the technologies mature and their production cost becomes more competitive.

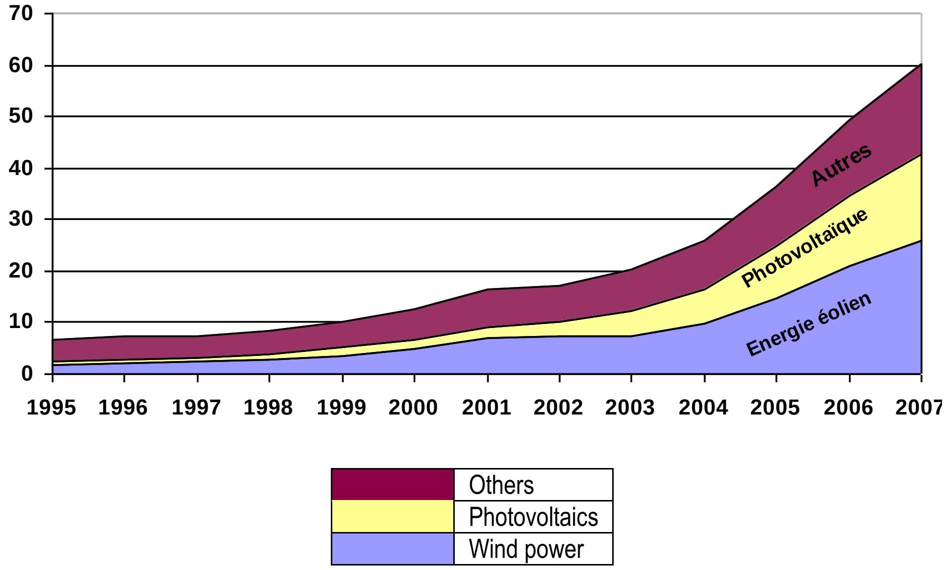
2.2.2. International trend

A favourable world market:

- An environment conducive to the development of renewable energy:
  - Technologies in continual development, tending to reduce investment and operating costs and produce competitive kWh or Btu.
  - Uncertainty and extreme volatility of fossil fuels.
  - Environmental awareness and the fight against global warming.
- A competitive cost per MW for some renewables (including wind) and a downward trend in the medium- and long- term for others.
- A high-potential market for: wind, solar thermal and photovoltaics.
- More than US$ 60 billion invested in 2007 in renewable energy projects worldwide[5].
- A CO2 emissions market of approximately US$ 233 billion in 2050 (compared to US$ 60 billion in 2007).

[5] Ref. REN21

Figure 14 - Annual investment in new renewable energy capacity (in billions of USD, excluding large hydroelectric plants)



- The total installed capacity in late 2007, all segments combined, was estimated at around 240 GW, excluding large-scale hydropower, equivalent to nearly 6% of global electricity capacity.
- Wind farms in 2007 totalled almost 100 GW, with average annual growth of 25%.
- 50 million households worldwide have solar water heating systems, 65% of which are in China. The annual growth in this market is between 15% and 20%.
- 2 million geothermal heat pumps installed.
- Grid-connected solar photovoltaics is growing constantly.
- Biodiesel generation is under development.

The annual flow of investment in "Renewable Energy" technology per period in billions of USD[6] is:

Table 24 - Annual flows of investment in Renewable Energy technologies

	2003-2010	2010-2020	2020-2030	2030-2040	2040-2050
Hydro	41.7	34.1	24.7	24.1	20.6
Wind	19.8	79.4	84	36.7	41.6
Photovoltaic	11	35.2	79.4	78.3	77.3
Thermal solar	0.7	11.3	43.6	49	49.7
Marine	1.1	2.8	2.7	3.1	2.7
Total	74.3	162.8	234.4	191.2	191.9

Funding mechanisms and incentives:

- A guaranteed feed-in tariff and green certificates.
- A system of mandatory clean energy production quotas.
- A favourable Net Metering system: commitment to cover the difference between purchase/surplus integrated into the network.
- A Clean Development Mechanism (CDM) for project funding, through the carbon credit exchange system, in a range of 5% to 15% of the investment.

[6] Ernst&Young study on the Oujda technology centre, support document, 5 January 2009.

- Grants and guarantee fund: the GEEREF (global venture capital fund), with an initial €100 million to support private investment in developing countries; a U.S.-based international clean energy fund, with an initial US$ 2 billion; the German Federal Ministry's climate protection initiative: €400 million, of which €120 million are reserved for the international component.
- Credits and tax provisions.
- Bonus/subsidy – penalty/tax mechanisms to encourage energy efficiency.

2.2.3. Moroccan context: development dynamic

A considerable pool of renewable energy resources.

Wind

An estimated wind power potential of 25,000 MW across Morocco, including 6,000 MW at the sites studied (1.5 times peak demand).

Wind speeds vary from 9.5 to 11 m/s at a height of 40m in Essaouira, Tangiers and Tetouan, and 7.5 to 9.5 m/s in Tarfaya, Dakhla, Taza and El Aaiun.

Extensive distribution throughout the country makes it possible to supply remote, off-the-grid areas.

Solar

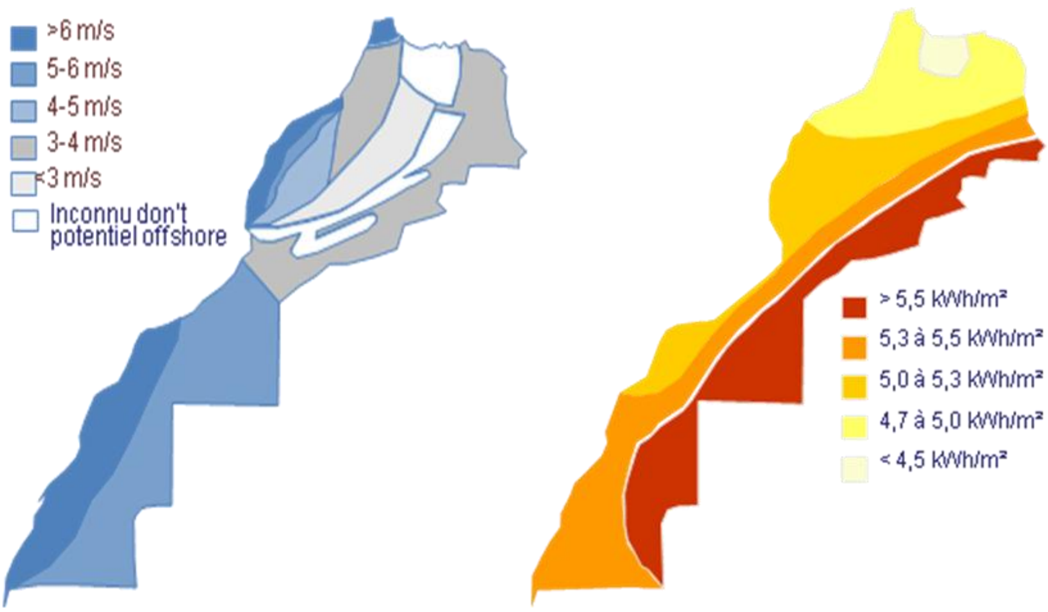
With more than 3000 hrs per year of sunshine, equivalent to radiation of about 5 kWh/m² per year, Morocco has a high solar capacity (average equivalent to Southern Europe). This potential is especially high in underserved areas in terms of grid and power production capacity.

The cost is particularly attractive (9% below the reference cost).

Biomass

Great potential especially in terms of household and agricultural waste, algae from Morocco's 3,500 km of coastline and other succulents.

Figure 15 - Geographical distribution of biomass and wind potential

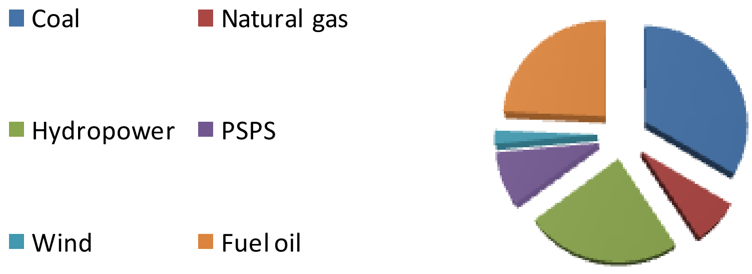


2.2.4. Development dynamic

<u>For wind power</u>

In 2008, the installed capacity in Morocco amounted to 5,292 MW, with wind power accounting for only 2.2% of the total. By way of illustration, the distribution of installed capacity in 2008 is presented below.

Figure 16 - Distribution of installed capacity in 2008



<u>For solar power</u>

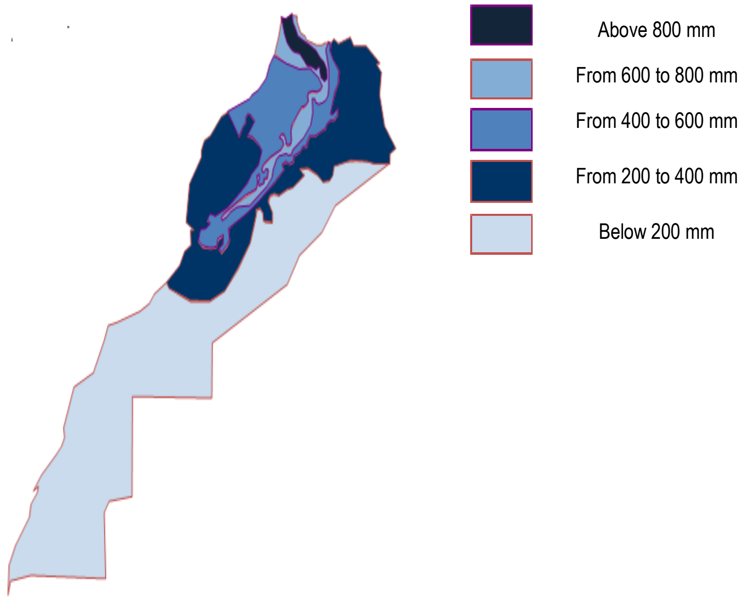
Developments have affected solar thermal and solar photovoltaics. An analysis of the increase in solar collectors nationwide shows an exponential curve: the number of collectors rose from 4,475 in 1994 to 40,332 in 2000, hitting 240,000 by 2008. In terms of solar photovoltaics, the number of recipient households was 1,500 in 1988, rising to 5070 in 2003 and finally 6,790 in 2008.

<u>For hydropower</u>

Hydropower is affected by limited rainfall and a drop in water levels in dams; 85% of Morocco's land surface area receives less than 300 mm of rain per year.

The total capacity of hydroelectric plants increased from 317 MW in 1956 to 363 MW in 1972, then to 963 MW in 2003 and 1,265 MW in 2008. The pumping and turbine station has a capacity of 464 MW. While hydropower capacity is increasing, the share of electricity produced by these plants as a proportion of overall electricity production is decreasing. Thus, the hydroelectricity share, which was 80% in 1956, fell to 54% in 1970 and 28% in 2003 and currently accounts for just 7%.

Figure 17 - Distribution of rainfall by area



2.2.5. Project portfolio

Wind power: projects implemented or planned

Table 25 - Wind power projects implemented or planned

Set-up date	Installed or planned facility	Installed capacity (MW)
2000	A.Torres Tetouan	54
2007	Cap Sim Essaouira	60
2009	Tanger Tetouan	140
2010	Energipro	200
2010	Tarfaya1	200
2011	Tarfaya2	100
2011	Energipro	400
2012	Energipro	400
Total	-	1,554

Solar power: projects implemented or planned[7]

Table 26 - Solar projects implemented or planned

Set-up date	Installed or planned facility	Installed capacity
2008	Solar PV	9 MW
2008	Solar thermal	200,000 m²
2009	Solar thermal Ain B.Mathar	20 MW
2012	Solar thermal CES	240,000 m²
2012	Solar PV	10 MW[8]
2012	Biomass	200 MW

Contribution of renewable energy types in 2007[9]

Table 27 - Contribution of renewable energy types

Application	Installed capacity	Electrical energy yield or equivalent (GWh)
Solar PV	9 MW	16.3
Solar thermal	200,000 m²	85.66
Wind	124 MW[10]	460
Biomass	3,000 m³	0.26
Micro-hydro plants	150 KW	1.3
Total	-	563.52

The contribution of large-scale hydropower was estimated at 902 GWh in 2007, and that of renewable energy at 1,465 GWh, accounting for 4% of Morocco's energy balance.

2.2.6. Constraints to developing renewable energy

Current situation

- Capacities for developing renewable energy projects extremely limited compared to identified potential.
- Marginal contribution of foreign funds.
- Limited government incentives.

[7] Decentralised renewable energy + Equipping new cities (Tamesna, Lakhyayta, etc.).
[8] Excluding the Solar plan, which is covered below.
[9] Source: CDER.
[10] Including 10 MW from Lafarge.

Constraints

- Lack of legislative and regulatory framework concerning the development of renewable energy.
- Renewable energy low on the priority lists of national infrastructure development programmes.
- Competition from subsidised energy sources: e.g. butane and fuel oil.
- Low level of information and awareness among general public.
- Lack of research and development that could lead to innovation and technological adaptations.
- "Project" approach not creating visibility for potential investors or deployment of suitable financial mechanisms.
- Budget allocations and financial incentives insufficient for real development of the economic, social and environmental added value of renewable energy.

2.2.7. Renewable energy development strategy

The new energy vision is structured around the following points:

- Renewable energy: a major aim of the New Energy Strategy.
- A diversified national energy mix aimed at developing renewable energy on a market basis using 4 strategies:
  - Progressive development of Power Purchase Agreements (PPA)
  - Promotion and development of large-scale projects for exporting green power.
  - Development of self-production.
  - Strengthening the capacity of the grid.
- Contribution to reducing energy dependence.
- Controlled expansion of energy resources to support economic development.
- Positioning Morocco in regional and international renewable energy and energy efficiency markets.
- Development of a renewable energy equipment and facilities industry.

2.2.8. The objectives of the new strategy

- Contribution to diversifying and securing supplies.
- Sustainable human development: widespread access to energy and creation of income-generating activities.
- Control of energy costs to ensure the competitiveness of domestic production.
- Optimisation of the electric load curve.
- Environmental protection: control of growth in greenhouse gas emissions, 60% of which is from energy production.
- Conservation of natural resources: water, forest cover, biodiversity, combating desertification.
- Economic development and investments.
- The industrial rise of a new sector, regional positioning to win.
- Increased mobilisation of international cooperation and strengthening regional partnerships (Euro-Mediterranean, African, Arab).

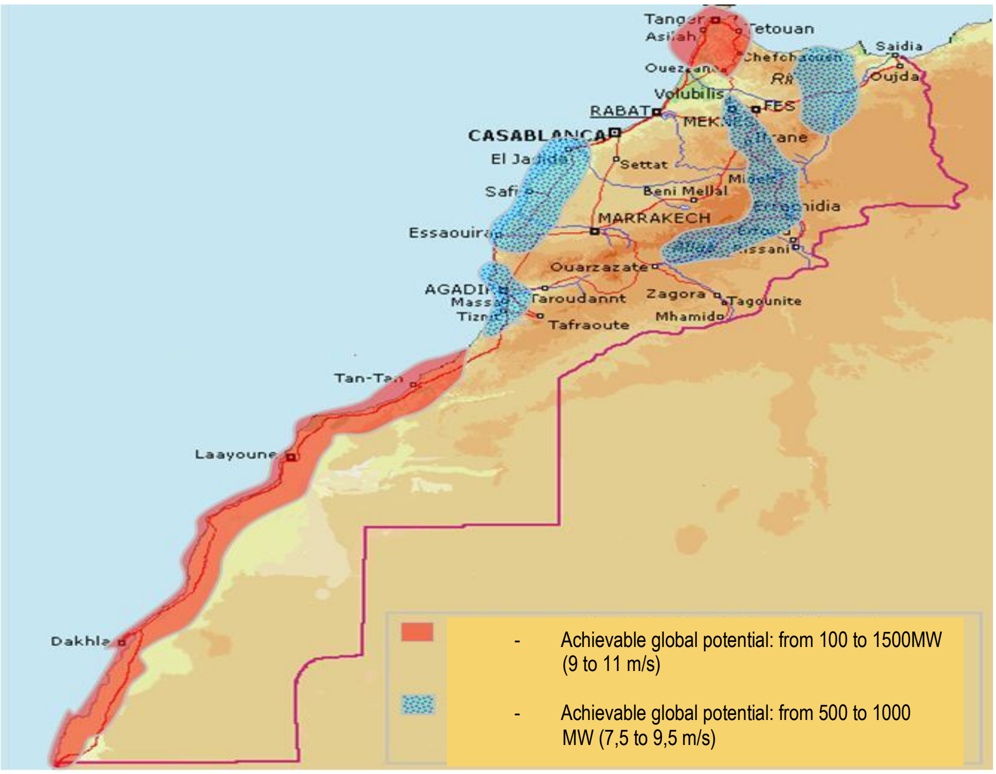
2.2.9. Vision for 2020

<u>Wind power: a competitive industry</u>

- Average wind speed exceeds 9 m/s at a height of 40 m in several regions.
- Achievable potential (2013-2020)[11]: 1,300 MW[12].
- 9 million tonnes per year CO_2 avoided.
- 2.6 MTOE per year saved.
- 8,500 new jobs.

The following map identifies areas of potential wind energy development.

Figure 18 - Potential areas for developing wind energy



<u>Solar power: shaping the future</u>

Achievable potential:

- Photovoltaics: 1,080 MWp
- Ground coverage ratio: 1,260,000 m²
- Concentrated solar power: 2,000 MW.
- 3 million tonnes per year CO_2 avoided.
- 925,000 TOE per year saved.

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[11] Source CDER/GTZ.
[12] Need to increase the capacity of the grid.

- 12,920 new jobs.

With a specific focus on concentrated solar power (CSP), Morocco is committed to participating in the Mediterranean Solar Plan, as part of the Union for the Mediterranean, by developing a number of large-scale projects. Within this framework, an integrated project to generate electricity from solar energy, called the "Moroccan Solar Energy Project", was launched in November 2009 by the country's highest authorities. This project is part of the energy strategy, which gives priority to developing renewable energy and sustainable development. It seeks to establish a total production capacity of 2000 MW by 2020. This figure is equivalent to 38% of the total installed capacity for late 2008 and 14% of electric power by 2020.

This is a massive initiative with an estimated investment cost of US$ 9 billion. The project contributes substantially to reducing the country's energy dependency and energy bill, as well as CO2 emissions, to ensure sustainable economic and social development.

The solar power projects will be built in Ouarzazate, Ain Beni Mathar, Foum Al Oued, Boujdour and Sebkhat Tah.

The characteristics of these projects are summarised below:

Table 28 - Characteristics of future solar energy projects

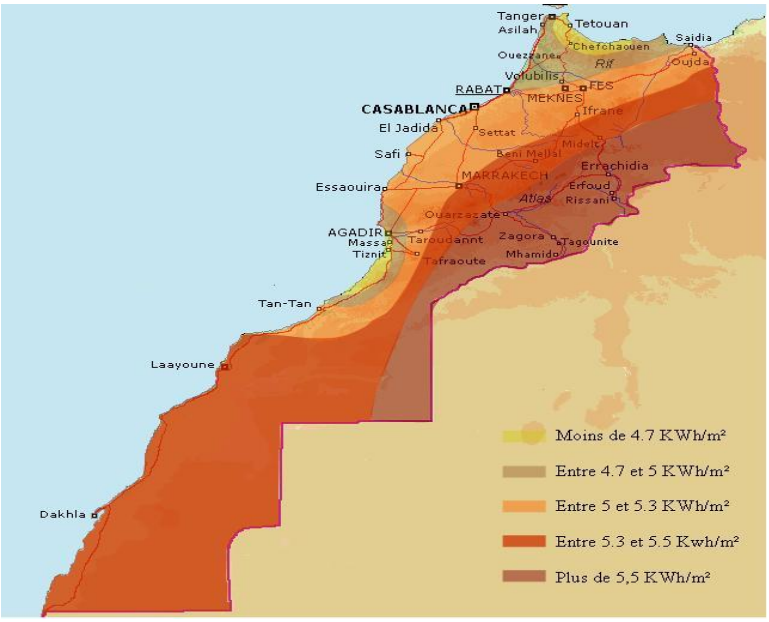
Project	Surface area (ha)	Capacity (MW)	Production (GWh per year)	Direct Normal Irradiance (kWh/m² per year)
Ouarzazate	2,500	500	1,150	2,635
Ain Beni Mathar	2,000	400	835	2,290
Foum Al Oued	2,500	500	1,150	2,628
Boujdour	500	100	230	2,642
Sebkhat Tah	2,500	500	1,040	2,140

These projects will result in:

- 3.7 million tonnes per year of CO2 avoided (perhaps to be counted as a monetary saving on behalf of the sector and as an additional external cost for competitor industries).
- Annual savings of 1 MTOE, equivalent to around €335 million.

The map below shows the development potential of this source of energy, expressed in kWh/m².

Figure 19 - Development potential of solar power



For low-temperature solar thermal, the 2020 targets are as follows:

Table 29 - Low-temperature solar thermal targets

Date	Target (m²)	Produced energy (GWh/yr)	Energy equivalent (TOE)	CO2 avoided (T/yr)	Capacity saved (MW)	Jobs created
2020	1,260,000	1,154	75,600	682,000	400	680

The stated objectives for photovoltaics are positive, but they may be reviewed in the light of recent decisions to develop large-scale power production (CSP: 2,000 MW by 2020). The initial targets are shown below, for information:

Table 30 - Solar PV for decentralised applications

Date	Electrical capacity (MW)	Energy (TOE)	Investment (M dirhams)	CO2 avoided (T)	Jobs created
2020	80	35,000	9,600	90,000	5,000 jobs

Table 31 - Solar PV connected to the grid

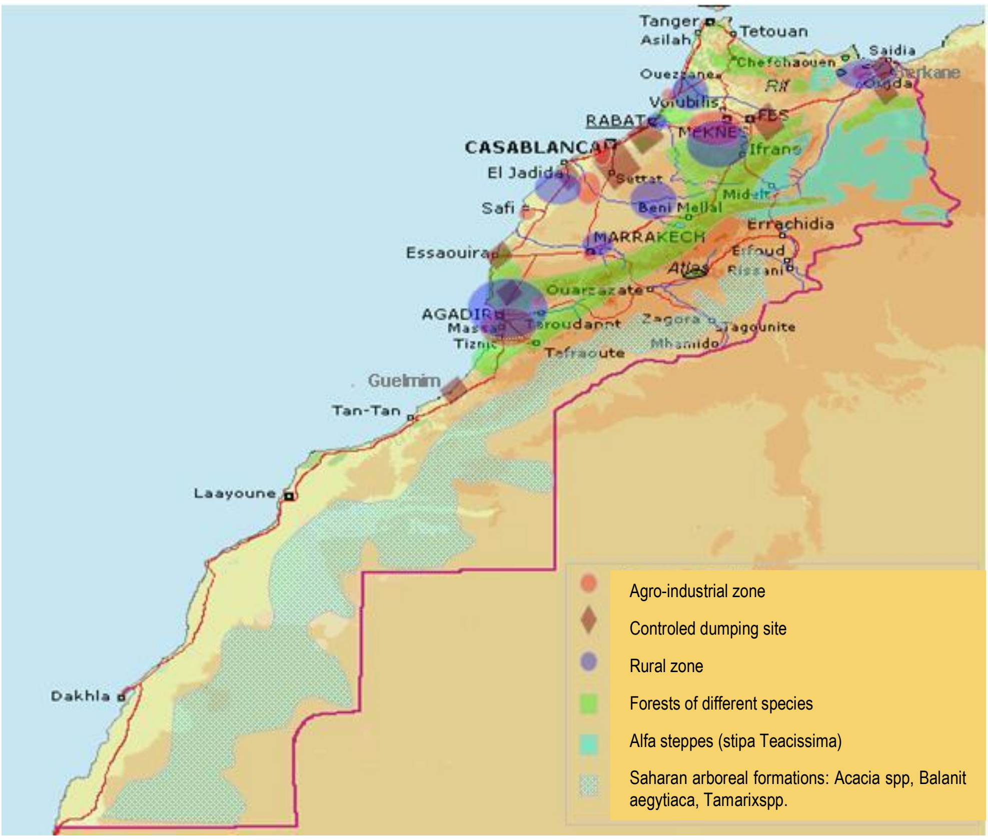
Date	Electrical capacity (MW)	Energy (TOE)	Investment (M dirhams)	CO2 avoided (T)	Jobs created
2013- 2020	1,000	375,000	40,000	1,125,000	5,000 jobs

Biomass: surprising potential

The achievable potential is estimated at 950 MW, resulting in 4.8 million tonnes of CO2 avoided per year and 2.1 MTOE per year saved, in addition to the creation of 2,200 jobs.

Areas with high development potential for this resource are indicated on the following map:

Figure 20 - Areas with high development potential for biomass



The objectives for 2020, with or without biomass, are presented in the following table:

Table 32 - Objectives for 2020

Scenario	Electrical capacity (MW)	Energy saved (TOE per year)	Billions of dirhams	CO_2 (MT)	Jobs created
Without biomass	500	1,130,000	10	2.5	1,100
With biomass	950	2,150,000	21	4.8	2,100

2.2.10. Accompanying measures

The accompanying measures are based on three main components:

Energy development fund:

- Creation of a Special Allocation Account (CAS) (Moroccan Finance Act 2009).

  The resources are US$ 1 billion, distributed as follows:
  - Donations: US$ 800 million.
  - Hassan II Fund: US$ 200 million.

Use by agreement

The objectives are:

- Strengthening and preserving energy production capacities, particularly from renewable energy, with the aim of reducing energy dependence.
- Financial support for:
  - Increased energy efficiency.
  - Studies and technical assistance.
  - Support for businesses providing energy services.

New legislative and regulatory framework

- New law aimed at developing renewable energy on a large scale, by establishing:
  - A legal status for renewable energy.
  - Access rights for private developers to the transit network.
  - The right of developers to supply the domestic market.
  - The right of developers to export electricity generated.
- A bill converting the CDER (Moroccan Renewable Energy Centre) into the Renewable Energy and Energy Efficiency Development Agency.

Research and development

An important lever for renewable energy development:

- Develop renewable energy in Morocco through scientific research to build expertise for developing renewable energy technologies.
- Use clean technology to enhance energy efficiency.
- Encourage the transfer of technology through universities and research centres.
- Encourage the creation of energy efficiency and renewable energy centres of expertise.
- Set up regional technology platforms dedicated to energy efficiency and renewable energy.

- Establish mechanisms to support research and development in renewable energy.
- Create a special prize dedicated to the best renewable energy research project.

2.3. Energy efficiency

Energy efficiency undoubtedly deserves to be counted as a fourth type of energy production, after fossil fuels, renewables and nuclear energy. Morocco aims to achieve 12% to 15% savings in energy consumption by 2030.

However, the plan is not to consume less energy, but to consume better. Indeed, the country has been experiencing a steady growth rate through the momentum gained by the large number of major projects either completed or underway in virtually all sectors: port and airport infrastructures, motorways, the emergence programme, the "Plan Azur", etc.

The Ministry of Energy, Mines, Water and the Environment has set up a National Priority Action Plan targeting both energy supply and demand.

Thus, to improve energy efficiency in key sectors of the national economy, the Ministry of Energy, Mines, Water and the Environment has entered into partnerships with the Ministries of Housing, Tourism, Public Education and Industry. Other agreements will also be concluded with other major players on the national energy scene. The objective sought through these partnerships is to introduce energy efficiency technologies in a sustainable manner. This will be achieved by encouraging industrial companies to use renewable energy or cogeneration; making energy audits common practice among small and medium-sized enterprises; developing an energy efficiency code for buildings which includes a move towards solar water heaters; making the use of low-energy bulbs more widespread; and using energy-efficient public lighting equipment.

These actions cannot be implemented without a legislative and institutional framework commensurate to the country's ambitions in this area. This is why this ministerial department has embarked on creating an appropriate legislative and institutional framework for enhancing energy efficiency.

2.3.1. International trend

High investment and employment potential:

- An international products and services market set to rise to US$ 2,740 billion by 2020 (compared to US$ 1,370 today), with energy efficiency responsible for half the savings.
- Energy consumption due to buildings represents 30-40% of overall consumption and greenhouse gas emissions.
- The energy costs of "new generation" buildings[13] represent an energy saving of up to 80% compared to traditional buildings.
- Energy efficiency is a job-creating sector: creation of 3 to 4 times more jobs compared to an investment in new capacity and a 50% cheaper investment cost compared to the creation of new capacity[14].
- In developing countries, the potential of energy efficiency is estimated at 30-50% of consumption[15].
- Energy efficiency represents 65% of the potential for reducing CO2 emissions (IEA).

In the case of Morocco, the potential savings and sectors to be mobilised are as follows:

- Possibility of saving more than 15% of energy by 2030.

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[13] Ernst & Young
[14] MedEnec
[15] GTZ

- Economic sectors to mobilise:
  - Industry: upgrading enterprises.
  - Service and residential: a growing demand for comfort.
  - Transport: existing vehicles old and inefficient, increasing mobility.
- Control of changes in energy intensity: benchmark.

2.3.2. Moroccan context: growth dynamic

Expectations

- Reduction of energy dependence: consume more but consume better.
- Control of energy costs to ensure the competitiveness of domestic production.
- Optimisation of the electrical load curve.
- Environmental protection: limiting greenhouse gas emissions, 60% of which is from energy.
- Economic development and investments.

Three essential conditions

- Increased energy efficiency.
- Electricity savings during peak hours.
- Structural changes to transport behaviour.

Three prerequisites

- Proactive policies.
- Mobilisation of all stakeholders.
- Awareness-raising and communication.

Buildings sector

- The buildings sector consumes about 36% of the country's total end energy: 29% by the residential sector and 7% by the service industry.
- Lack of energy efficiency considerations on several levels:
  - Design and construction: topography, orientation, room layout, building materials, insulation, ventilation, etc.
  - Energy-consuming equipment: hot water, air conditioning, heating, lighting, lifts, energy-consuming household appliances, etc.
  - Energy management: energy audits, invoice tracking, regulation, control systems, equipment management.
- Lack of a coordination body for the sector's energy efficiency policy.
- Few examples demonstrating the profitability of such projects in the country that could motivate financial institutions to get involved.
- Near absence of ESCOs (Energy Service Companies) in Morocco.
- Lack of Moroccan energy efficiency standards for equipment, building materials and household appliances.

- Lack of awareness among construction professionals and the general public of the scope and impact of energy efficiency techniques in building design, construction and equipment.

Industrial sector

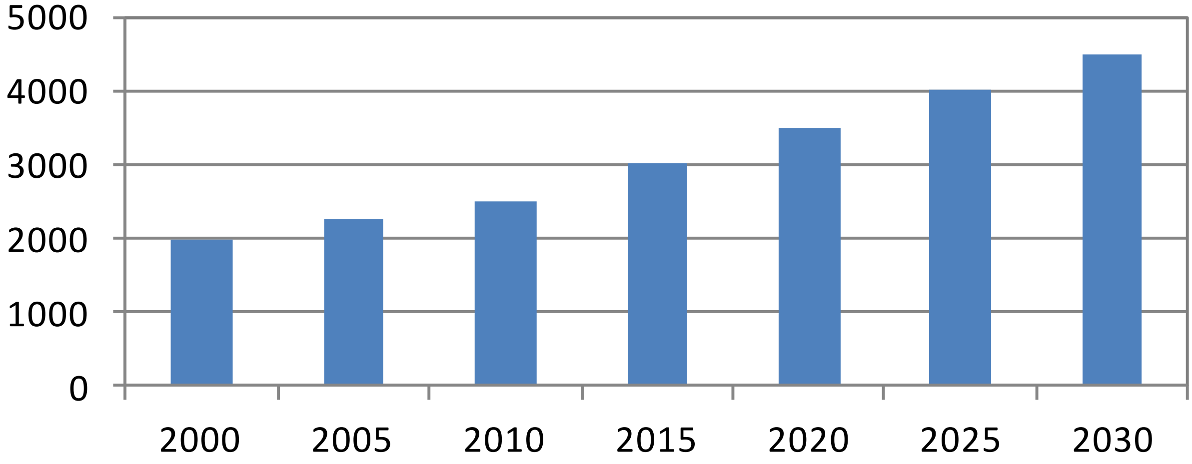
- Imports of energy products make Morocco extremely externally dependent.
- The volatility and instability of the prices of petroleum products firmly place the Moroccan economy as a whole, and all potential energy-consuming sectors, under pressure from fuel and electricity costs.
- The industrial sector has about 7,000 industrial units consuming about 7,000 GWh of electricity and nearly 799,000 TOE of thermal energy, or more than 30% of the total energy[16].
- This sector represents a large share of overall energy savings, estimated at 15% of national energy consumption by 2020.
- At the end of 2007, consumption of liquid fuels (fuel oil) and gas (propane) in industry nationally, excluding the ONE's fuel consumption, were roughly estimated at 967,000 TOE and 164,000 TOE respectively.
- An approximate total of 2,200 steam boilers, which are often old-generation and low energy efficiency, are under pressure from fuel costs and maintenance.
- Substantial support needs for optimising electrical consumption (power factor, subscribed demand, speed variators, etc.) and heat consumption.

Transport sector

- 24% of the country's total energy consumption.
- An ever-increasing number of vehicles on the road. The total was assessed at 2,147,000 in 2006, of which 300,000 were commercial vehicles.
- A sector characterised in particular by:
  - Ageing vehicles (nearly 15% are over 20 years and 55% over 10 years old).
  - A lack of strategies for optimising travel in most cities.
  - Potential for improving the organisation of public transport management.
  - Poor coordination between departments and stakeholders.
  - An inadequate road network and poor traffic management.
  - A largely underfunded area (operating and capital expenses).
  - A range of sector activities and a wide variety of players.
  - Many exemptions awarded in the roadworthiness test.
- The consumption of diesel in the transport sector represents about 50% of total diesel consumption in the country.
- Nearly 15% of the country's total greenhouse gas emissions come from transportation.
- Road transport accounts for 23% of these emissions.

[16] Source: CDER

Figure 21 - Diesel consumption in the transport sector[17] (in Thousands TOE)



2.3.3. Constraints on developing energy efficiency

Current situation

- Poor integration of energy efficiency in key sectors of the national economy.
- Marginal contribution of foreign funds and limited incentives from the authorities.
- Limited incentives.

Constraints

- Lack of regulatory framework governing the sector and an Agency that is operational in nature.
- Energy efficiency considered as a low priority by national infrastructure development programmes.
- Inadequate human resources with the required knowledge and skills.
- Low level of information and awareness among the general public.
- Research and development and technological innovation and adaptation expertise are insufficiently involved.
- "Project" approach does not create good visibility for potential investors or deployment of adequate financial mechanisms.

[17] Report on the study of measures and programmes to reduce greenhouse gas emissions.

2.3.4. New strategy to boost energy efficiency

The table below summarises the new long-term strategy.

Table 33 - Summary of the new strategy to boost energy efficiency

		Lever	Uptake strategy	Expected impact
Integrated perspective	Energy mix	Direct use of the optimal fuel for each activity – E.g. water heater: gas, solar or electric?	Energy efficiency Act, tax incentives, etc.	
Segments	Buildings	Optimisation of thermal insulation (heating-cooling)	New buildings and energy-efficient consumption code	
		Efficiency of equipment	Classification of equipment and tax and customs incentives	
		Low-energy lighting	Prohibition of incandescent light bulbs in the short and medium term	
	Administration and public lighting	Efficiency of public lighting/signage	Planned public lighting, LED traffic lights, etc.	
		Efficiency of electrical consumption in the government sector	Similar to the building sector	
	Industrial/ Transport	FDI: preferential attraction of low-consumption industries	Widespread energy audits	
		Replacing old vehicles with newer models Public transport	Strengthening the roadworthiness test system	

: Minimum impact, *: Maximum impact*

2.3.5. Legislative and organisational reforms

Implementation of this new strategy is based on the renovation of legislation and organisation of the energy sector. To this end, several bills will be enacted into law in order to:

- Promote renewable energy and energy efficiency, for which the CDER, converted into an Agency, will be the linchpin.
- Reorganise the power sector in order to integrate it better into the Euro-Mediterranean market, promote the construction and financing of production capacity, better organise its various components and ensure its regulation.
- Develop the natural gas sector to make it an alternative to oil and coal.
- Boost the downstream oil sector by increasing its competitiveness and liberalisation.
- Improve the safety and risk prevention rules in the energy infrastructure.
- Protect the environment and citizens' health by imposing standards that comply with international standards for solid, liquid and gas emissions in energy production and use.

2.3.6. Communication

Communication will be made a priority in order to convey the goals set by the strategy and obtain the support of all stakeholders.

3. Water needs for energy

Hydropower has been a key component in the design of water infrastructure, particularly in the Sebou and Oum Er Rbia basins.

It was thus in order to make use of the country's potential water wealth that Morocco's PDAIREs took the constraints of hydroelectric production into account. These development plans have always defined and adopted the water management schemes that promote energy production to the greatest extent, not only as a complementary component to other priority uses (drinking water and irrigation) but also as a structuring component. Several steps have been taken as part of the development plans to promote hydropower. These provisions include:

- The choice of water management schemes to be implemented (number of dams, choice of areas for irrigation, particularly in the Oum Er Rbia basin).
- Oversizing dams to maximise energy production (as in case of the following dams, for example: Ahmed El Hansali, A Wahda, Matmata Tunnel, Idriss I, and Oued El Makhazine).
- Construction of re-regulating dams to enable hydroelectric plants to operate at full capacity with flow rates much higher than the quantities extracted for irrigation and drinking water. The purpose of these dams is to compensate the volumes that pass through the turbines and those that are extracted for drinking water and irrigation, in order to prevent water loss. Compensation consists in temporarily storing the water used in electricity production, to be released only when irrigation is required.

The importance of hydropower lies in the flexibility of its availability and the advantage of being able to use it during peak hours, while its cost is very low compared to that of equivalent thermal generation. The PDAIREs include the construction of around forty hydroelectric plants with an installed capacity of approximately 2,000 MW. These hydroelectric plants have been planned, designed and substantiated to ensure average production of about 3,700 GWh per year (see table below).

The water management strategies adopted in the PDAIREs prioritise the satisfaction of drinking water and irrigation needs. No water has been reserved for hydroelectric generation. Hydroelectric plants simply pass water that will later be used for irrigation and drinking through turbines. This management method, which does not result in losses into the sea, ensures maximum efficiency since it allows water to be used in both energy production and drinking water or irrigation. As a result, hydropower generation is not included in the balance of supply and demand.

Table 34 - Characteristics of hydropower plants planned in the PDAIREs

Basin	Plants planned in the PDAIREs	Performance	
		Installed Capacity (MW)	Energy capacity (GWh)
Loukkos, Tangiers and Mediterranean coastlines	4	60	
Moulouya	2		
Sebou	15		1,377
Oum Er Rbia	19		2,059
Tensift	1	15	34
Souss-Massa-Draa	1	15	34
Guir-Ziz-Rheris	-	-	-
Sahara	-	-	-
Total	42		3,500

3.1. Completed energy plants

Hydroelectric plants completed up to 2007 had a total installed capacity of around 1,730 MW, of which nearly 460 MW was from the Afourer turbine and pumping station. These plants were planned, designed and substantiated to guarantee average energy production of around 2,400 GWh.

Of the 42 plants detailed in the PDAIREs, 23 have been completed. Most of these hydropower stations are located in the Oum Er Rbia and Sebou basins. They were planned, designed and substantiated to guarantee average energy production of around 2,400 GWh per year. The following table gives the performance of these hydroelectric plants by river basin.

Table 35 - Performance of completed hydroelectric plants

Basin	Plants completed	Performance	
		Installed Capacity (MW)	Energy capacity (GWh)
Loukkos, Tangiers and Mediterranean coastlines	4	60	
Moulouya	2		
Sebou	4		772
Oum Er Rbia	11		1,535
Tensift	1	15	34
Souss-Massa-Draa	1	15	34
Guir-Ziz-Rheris	-	-	-
Sahara	-	-	-
Total	23		2,400

The average annual energy yield of all the completed dams is estimated at around 1,200 GWh, or about half the expected results. The average production deficit is estimated at around 1,200 GWh per year (Appendix 10).

Hydroelectric generation has clearly suffered the impact of climate change, resulting in decreased water reserves and lower heads at all dams.

Volumes flowing through turbines at all hydropower plants over the last decade are estimated at around 8 billion m^3, or an average yield of about 0.3 kWh/m^3.

Exclusive turbines are operated at the Al Wahda and Oued El Makhazine dams because of the quantity of water resources available at these two dams, due to delays in equipping the associated agricultural areas.

3.2. Prospects for developing hydroelectric power

The main hydroelectric plants planned in the PDAIREs are presented in the table below. These hydroelectric plants, with a total installed capacity of nearly 370 MW, are planned to ensure average energy production of about 720 GWh per year.

Table 36 - Major hydroelectric plants planned in the PDAIREs

Dam	Installed capacity (MW)	Average energy capacity (GWh/yr)
Imezdilfane	63	95
Taskdert	38	47
Tajmout	28	35
Mechra Sfa	29	69
Merija	31.4	74
Mechra El Hajjar	7	20
Asfalou	20	14.2
Mdez - Ain Timedrine	150	370
Dar Khrofa		
Total	367	724

The significant reduction of water supply observed in the last thirty years means that this production would be about 300 GWh per year.

The construction of these dams would result in an increase in water body surface area of about 5,000 ha. This increase in water bodies would result in an increase of about 100 Mm^3 per year evaporated volume, a shortfall estimated at nearly 500 million dirhams.

In conclusion, the impact of climate change has resulted in an energy loss of about 1,500 GWh per year, of which nearly 1,200 GWh per year is observed in operational hydropower plants.

With the expected decline in water resources in coming years due to climate change, this loss would be in the region of 2,000 GWh per year.

The construction of dams for energy, planned for the Sebou and Oum Er Rbia river basins, may result in water loss by evaporation of around 100 Mm^3 per year, with the consequent risk of aggravating water shortages in the Saiss and the agricultural areas supplied with water from the Oum Er Rbia.

A water-energy analysis is needed to assess the impact of the construction of planned hydropower plants.

3.3. Using water for energy

Water use in the energy sector in Morocco consists mainly of electricity generation (cooling thermal power plants and turning turbines at hydroelectric plants). Water abstraction for industrial purposes for other energy uses is relatively minor.

3.3.1. Water for cooling thermal power stations

Electricity is currently produced in Morocco mainly in steam cycles where water is pressurised, heated, vaporised and superheated before being expanded in the steam turbines that drive generators. These processes require large amounts of water. The turbine generators that convert the mechanical and thermal energy contained in water vapour into electricity consume little water since they operate in a closed circuit. Large amounts of water are, in contrast, used to cool the turbine generator condensers. This equipment is designed to collect as much heat as possible. The energy content of the steam is depleted, in a manner of speaking, and the amount of electricity that can be produced is thereby increased.

Most of the water abstracted by power plants is therefore used as coolant. This water is extracted upstream from the plants at a given temperature (the temperature of the sea or groundwater, or the river where the plant is built). It cools the turbine generators through the condenser and is discharged downstream of the plants at a higher temperature. It should be noted that for electricity generation, around 97.5% of the water is returned instantly to the environment (low consumption).

Morocco's current thermal power plants are located on the coast and sea water is used for cooling, except for the new solar thermal plant at Ain Beni Mathar (combined-cycle plant with integrated solar array, with a capacity of 472 MW of which 20 MW are from solar), which abstracts from the region's aquifer, the combined-cycle plant built near the river Tahaddart (385 MW combined-cycle capacity) and the Jerada coal-fired plant that is now being decommissioned.

In the absence of reliable data, estimates will be established on the basis of average consumption of 60 l/kWh or 60 m^3/MWh, equivalent to 0.06 Mm^3/GWh. Moreover, it is considered that from 2015, two-thirds of the future capacity planned for 2030 will be developed along the coast and a third in the country's interior. The calculations for thermal power plants will therefore take into account only those that are planned for, or have been built in the country's interior. Only the tertiary or cooling circuit is counted; the demineralised water consumption of the primary and secondary circuits is neglected.

Based on these assumptions, estimates of water abstraction for cooling thermal power plants in the Moroccan interior would be about 1,200 Mm^3 in 2030 compared to the current volume of 172 Mm^3. These estimates do not include consumption by the new solar programme (2,000 MW by 2020).

Thus, the estimated water abstraction in 2030 corresponds to that of a population of about 3 to 4 million. Closed-circuit cooling (using an air-cooling tower) requires much less water but since the water must be of good quality, it tends to require extensive treatment.

It should be noted that:

- Water abstracted for open-circuit cooling is fully restored to its original natural resource (this is hard when the water is drawn from an aquifer) with no degradation other than thermal pollution. Large volumes are generally required. Only rivers with high flows (or relatively large water bodies) are suitable for cooling large power plants.
- In practice, water abstraction and consequently a plant's energy output, may be reduced due to water temperature, in order to maintain a threshold temperature for release into the environment. These conditions may be encountered several weeks per year.
- Abstraction along the coast (sea water) is not counted, given that coastal locations are not constrained in terms of water resources.
- The thermodynamic efficiency of power plants, which ranges from 33% for certain nuclear systems to 38% for conventional power plants, and up to 55% for combined-cycle plants, determines the power requirements of condenser cooling. Any technology that significantly improves efficiency results in a lesser dependence on water resources.

3.3.2. Water for the needs of the phosphate sector

The OCP Group, a world leader in the phosphate sector, has undertaken an extensive programme to develop its mining and industrial capabilities, which will eventually increase its capacity from 23 to 50 million tonnes of phosphate per year. The effort to increase production capacity is naturally accompanied by an increase in water requirements, set to rise from 66 Mm^3 per year currently to over 158 Mm^3 per year in 2030. The amount of water required per tonne of phosphate concentrate produced is between 1 and 3 m^3. This water demand is taken into account in a responsible manner in the OCP Group's development strategy. To safeguard strategic groundwater resources as it continues to grow, the phosphate industry will abstract only from freshwater sources, through the following actions:

- Geographical reallocation of water abstraction to the upper Oum Er Rbia basin.
- Sea water desalination and wastewater treatment to meet emerging needs.

3.3.3. Water for hydroelectricity

Generally speaking, hydropower is not considered relevant for inclusion in this water-energy assessment, for the following reasons:

- This energy source is not one that "abstracts" or "consumes" water. The water passed through the turbines is directly available for other purposes downstream, in particular agricultural uses.
- Its development is often associated with the creation of new resources (reservoirs).

3.3.4. Energy dependence for water

Energy dependence for exploiting water as a resource is relatively high in Morocco, for several reasons:

- The level of water abstraction is very high, primarily for irrigation needs, which creates an extremely strong dependence on electricity (Goossens and Bonnet, 2004).
- This dependence will grow as needs increase and increasingly expensive energy resources are required (groundwater resources, transfer of distant resources).

- The level of per capita energy consumption, which is significantly lower than that of developed countries, helps to explain the high relative weight of the water supply.
- However, water utilities (drinking water and sanitation) are still underdeveloped in the country. These services, which are currently responsible for a fairly small share of energy dependence, could, as they develop, significantly increase the associated energy requirement. In this sense, technological choices are likely to have primary importance, as the energy and environmental impact can vary significantly between different effluent and sludge collection and treatment methods. These notions of technological choice are also rather topical in France, in terms of local government options for rural or rural-urban fringe contexts (collective or independent sanitation).

IV. Water-energy analysis for 2030

The approach adopted for managing multipurpose dams gives priority to meeting drinking water and irrigation needs. No water has been reserved for hydroelectric power generation. Hydroelectric plants simply pass water that will later be used for irrigation and drinking through turbines. This management method, which does not result in losses into the sea, ensures maximum efficiency since it allows water to be used in both energy production and drinking water or irrigation. As a result, hydro generation does not affect the balance of supply and demand.

Climate change has resulted in a significant reduction of energy production from dams and thus the expected performance of hydroelectric plants planned.

Opportunities for developing water resources are based mainly on energy-intensive solutions. This is the case for sea water desalination projects, the water transfer project and projects to develop sanitation, reuse treated wastewater, or use energy-intensive conventional resources to meet the demand for potable water and irrigation. Energy consumption of the water sector by 2030 is estimated at around 6,145 GWh per year, almost 5 times the energy output generated by the water sector.

The construction of the dams planned in the Loukkos, Sebou and Oum Er Rbia river basins may result in a negative impact on the development of irrigation schemes in the Dar Khrofa area of the Loukkos basin, the Saiss part of the Sebou basin and areas served by the Oum Er Rbia river.

Construction of a hydroelectric plant at the Dar Khrofa dam to first pass irrigation water through turbines will result in augmented local energy needs due to an increase in the required head of the water destined for irrigation.

The construction of dams intended solely for energy production would result in water loss by evaporation, estimated at about 100 Mm^3 per year, which could aggravate the water shortages, also affecting the agricultural areas that are supplied with water from the Oum Er Rbia.

The creation of the Mdez-El Menzel complex in the Sebou basin may reduce the scope of the project to protect the Saiss plain. Water passed through turbines at the El Menzel plant requires an additional head of over 200 m to serve the Saiss plain.

A water-energy analysis is therefore needed to assess the impact of the construction of planned hydropower plants on the development of water resources.

The energy sector must therefore expect a reduction in energy production from dams due to the problems of climate change and find other ways to meet the new energy demands of the water sector, which will experience a significant increase by 2030 due to the development of non-conventional water resources.

V. Water-energy-climate change analysis for 2050

1. Current observations

1.1. Globally

The IPCC report, released in 2007, provides evidence regarding changes in temperature, precipitation, sea level, melting snow and extreme events caused by climate change.

1.1.1. Rising temperature

Average air temperature increased by 0.6°C over the period 1901-2000 (0.74°C over the period 1906-2005). While the entire globe has experienced temperature increases, these have been greater at high latitudes and in the northern hemisphere. Eleven of the years between 1995 and 2006 rank among the twelve warmest since 1850.

1.1.2. Rising sea level

The average sea level has risen by 1.8 mm per year since 1961. An acceleration of this trend has also been observed (3.1 mm since 1993) but the relative responsibilities of climate fluctuations/climate change are difficult to assess.

1.1.3. Melting snow and ice

The annual ice extent in the Arctic Ocean has decreased by 2.7% per decade since 1978.

1.1.4. Precipitation

Observations on rainfall are more diverse. Increased precipitation has been observed in eastern North and South America, northern Europe and central Asia, while the Sahel, Mediterranean areas, southern Africa and southern Asia have experienced reduced rainfall.

1.1.5. Extreme weather events

During the twentieth century, an increase in the frequency and intensity of droughts and heat waves has been observed, along with an increase in intense rainfall (even in those areas that have seen an overall drop in precipitation). Cold spells have decreased. While an increase in intense cyclones in the North Atlantic has been observed since about 1970, in general no clear pattern emerges regarding the number of tropical cyclones that form each year.

1.2. In Morocco

Studies have revealed signs of climate change related to temperature, precipitation and extreme weather events. Significant trends have been observed over the last 45 years.

1.2.1. Temperatures

- Mean warming throughout Morocco from 1960 to 2000, with a maximum of 1.4°C in the southeast, towards the Midelt region. The warming seems to have been less intense in the north. In about two-thirds of the country, however, this warming exceeded 1°C.
- An upward trend in minimum temperatures. In the east, for example, minimum temperatures between 10°C and 15°C are less frequent while those between 15°C and 25°C have increased. Simultaneously, the extremes above 45°C rose slightly.

1.2.2. Precipitation

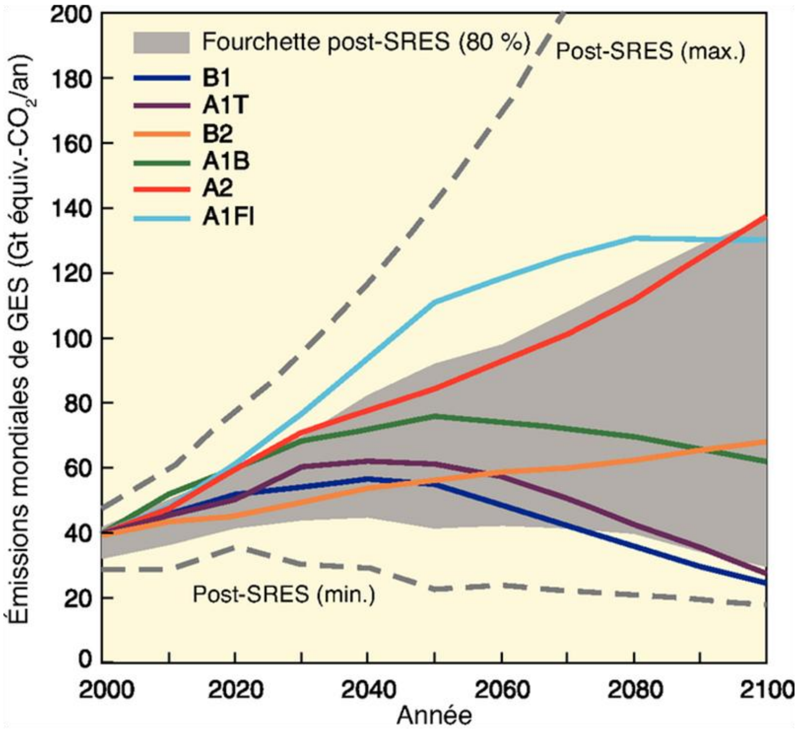
A marked decrease in rainfall collected annually. Annual rainfall has generally declined in a fairly significant way in the highlands of the east (Oujda, Midelt and Bouarfa), Saiss (Meknes) and the High Atlas (Ifrane). This shortfall has particularly affected winter precipitation, which affects the entire year.

2. The future climate

2.1. Globally

All scenarios for the twenty-first century predict a rise in average air temperature worldwide. Estimates of the increase in the Earth's average temperature by 2100 lie between 1.8°C (B1 scenario) and 4°C (A1F1 scenario). These "best estimates" are mean values, within a wider range of 1.1°C to 6.4°C.

Figure 22 - IPCC projected temperature changes for different socio-economic scenarios (IPCC, 2007)



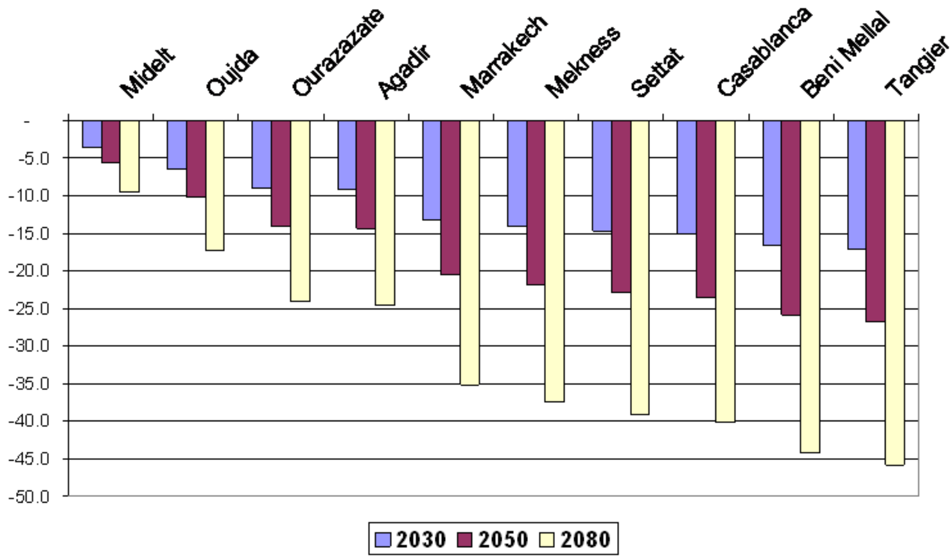
The IPCC reports, globally, a very likely increase in the frequency of extremely high temperatures, heat waves and heavy precipitation events and a decrease in average annual watercourse flows and availability of water resources in some dry regions at mid-latitudes and in the tropics (an increase at higher latitudes), with a high degree of confidence.

2.2. In Morocco

Scientific investigations carried out on climate projection throughout the twenty-first century have shown that climate change would result in increased temperatures and a significant reduction in rainfall.

- An increase in summer temperatures of up to 1.8°C by 2020, 3.7°C by 2030 and 6.2°C by 2080.
- A reduction in rainfall in the region of 5% to 15% by 2030 and 10% to 25% by 2050. The following graph illustrates the decline in annual rainfall according to the climate change model.

Figure 23 - Reduction in annual rainfall HadC M3, A2 scenario (reference period: 1961-90)



The 3°C increase in temperature and 15% reduction in rainfall by 2030 would substantially reduce annual runoff and consequently the volume of water used by existing and planned dams.

Analysis of droughts observed over the last thirty years shows that the deficit in runoff is almost double that recorded for precipitation (Appendix 8).

Initial results of studies in progress by experts from the World Bank have shown a correlation in which the water supply deficit is equivalent to 1.23 times the rainfall deficit, with a correlation coefficient of 0.92.

2.2.1. Impact on the volume of usable surface water

An analysis of the hydrological series for 1961-1990, 1945-2006 and 1979-2006 reveals the following findings:

- Series 1961-1990 and 1945-2006 are equivalent.
- Water supplies in the last thirty years (1979-2006) are almost 30% lower than in the 1961-1990 series. This series may therefore be a way to learn and appreciate the impact of climate change on water resources by 2030.

Hydraulic simulations using the 1961-1990 hydrological series, to which a 30% reduction was applied, were conducted to verify this conclusion (table below). The results of these simulations, detailed in Appendix 9, are summarised in the table below.

Table 37 - Hydraulic simulations with the 1961-1990 series

	1961- 1990 series	1961-1990 series 30% reduction	1961-1990 series 45% reduction
Al Wahda dam	1,733	1,323	1,135
Dar Khrofa	181	142	119
Bin Ouidane	691	542	460

An analysis of this table shows that a 30% reduction in water supplies would result in a 22% reduction in the regulated volume.

The impact of climate change can be estimated as follows:

By 2030

Precipitation would diminish by about 15% and would result in a reduction in water supplies in the region of 30%. The impact of climate change can be estimated from the regulated volumes calculated in hydraulic simulations performed on the basis of the observed series 1939-2006, reduced by approximately 22%.

These results are comparable to those obtained in simulations based on a series of simulations from 1979 to 2006.

By 2050

Precipitation would diminish by about 20% and would result in a reduction in water supplies in the region of 40%. The impact of climate change can be estimated from the simulations on the 1939-2006 observed series, with a reduction of around 35%.

The reduction in regulated volume by 2030 and 2050, despite the construction of new dams, can be explained by:

- The reduction in water resources at all dams, whether built or planned.
- Increased evaporation from all dams, whether built or planned.

Table 38 - Forecast exploited volumes, taking account of climate change

Basin	2010		2030		2050	
	Number. of dams	Exploited volume (Mm³/yr)	Number. of dams	Exploited volume (Mm³/yr)	Number. of dams	Exploited volume (Mm³/yr)
LTCM	10	558	16	950	18	830
Moulouya	5	718	10	620	11	600
Sebou	10	2,400	20	1,872	20	1,600
Bouregreg chawia	4	313	7	280	7	240
Oum Er Rbia	12	2,160	22	1,680	22	1,450
Tensift	3	100	8	132	8	115
Souss Massa - Draa	9	385	13	312	13	270
Guir-Ziz-Rheris	1	139	10	600	10	520
Sahara	1	30	1	30	1	30
Total	55	6,800	109	6,476	110	5,655

The impact of climate change in 2030 can be seen by comparing the results of simulations based on the 1939-1996 series with those performed as part of management plans based on the 1939-1982 series (see table below).

Table 39 - Comparison of the results of hydraulic simulations based on the 1939-1996 series with those based on the 1939-1982 series

Basin	1939-1982 simulations	1939-1996 simulations
Oum Er Rbia	3,950	1,680
Sebou	4,467	1,872
Loukkos, Tangiers and Mediterranean coastlines	1,077	950
Moulouya	1,042	620
Bou Regreg	662	280
Tensift	725	130
Souss-Massa-Draa	615	312
Southern Atlas	974	600
Sahara	30	30
Total	13,542	6,474

2.2.2. Impact on groundwater volumes

An estimate of the decrease in volumes available for groundwater recharge is presented below, using the following assumptions:

- The selected recharge coefficient is equal to 20%.
- Assumption 1: reduced rainfall would result in a 50% reduction in the number of rainy days and a 50% reduction in the height of daily precipitation.
- Assumption 2: reduced rainfall would result in a 70% reduction in the number of rainy days and a 30% reduction in the height of daily precipitation.

Table 40 - Natural recharge decrease coefficients

Year	2030	2050
Decrease in precipitation (%)	7	15
Decrease in groundwater flow (%)		
Assumption 1	21	45
Assumption 2	15.4	33

This exercise shows that a 15% reduction in precipitation could reduce the available recharge volumes by 33% to 45%. Henceforth, the percentage reduction in natural recharge by 2050 will be considered as 45% for the north and northwest, and 33% for the south and southeast of the country.

The reduced natural recharge will also lead to a decrease in output by natural outlets, assumed to be proportional to the reduction in natural recharge, an assumption that is considered acceptable for large reservoirs experiencing high rates of water abstraction.

Table 41 - Reduction in natural recharge in Mm³

Basin	2030	2050
Loukkos	85.3	38.4
Sebou	56.2	25.3
Moulouya	240.5	79.4
Bou Regreg	15.6	7.0
Oum Er Rbia	95.4	31.5
Tensift	25.8	8.5
Souss-Massa	32.8	10.8
Guir-Ziz-Rheris	44.3	14.6
Draa	48.1	15.9
Saquiat El Hamra and Oued Eddahab	0.4	0.1
Total	644.3	231.5

The decrease in surface water will also impact groundwater. Experts estimate that by 2050, projections of average annual flow of rivers and water availability will decrease from 10% to 30% in some dry regions at mid-latitudes and in dry tropical climates, some of which already suffer from water shortages.

This decrease is likely to compound the reduction in water supplies already registered at all dams between the 1970-2000 and 1945-1970 periods, estimated at 35%.

The phenomenon is further exacerbated by the increased water requirements of crops under the effect of higher temperatures.

Moreover, reduced surface runoff will lead users, particularly farmers, to fall back on groundwater reserves, access to which is relatively easy, to compensate water deficits.

In conclusion, expected climate change will progressively increase the pressure on groundwater reserves.

Evolution of irrigation return water

The volumes of irrigation return water will be affected by changes in the surface area of irrigated land and irrigation methods. The conversion of traditional irrigation to drip irrigation and the reduction of irrigated areas as a result of the unavailability of water resources, will significantly reduce irrigation return water volumes. The changes in irrigation return water when climate change is taken into account are presented in the following table, by basin.

Table 42 - Return of irrigation water taking climate change into account (Mm³)

Basin	2030	2050
LTCM	331.5	31.5
Sebou	75.3	75.3
Moulouya	122.0	122.0
Bou Regreg and Chawia	0.0	0.0
Oum Er Rbia	218.1	218.1
Tensift	208.3	186.0
Souss-Massa	23.1	18.9
Guir-Ziz-Rheris	0.0	0.0
Draa	44.7	44.5
Saquiat El Hamra and Oued Eddahab	0.0	0.0
Total	723.0	696.4

Evolution of outflows

Under the effects of climate change, water reserves will not have time to be replenished, as there will be a continual decrease in recharge volumes. The flow rates of natural outlets will decline continuously but will not catch up with the reduction in recharge, even with the assumption of a forced reduction of water abstraction volumes as a result of the unavailability of the resource. Shortages will thus tend to continue. Changes in natural outlets are presented in the table below, by basin.

Table 43 - Outflow through natural outlets taking climate change into account

Basin	2010	2030	2050
LTCM	383.05	306.4	245.2
Sebou	223.1	156.2	93.7
Moulouya	985.4	591.2	236.5
Bou Regreg and Chawia	20.42	11.2	5.6
Oum Er Rbia	544.8	354.1	212.5
Tensift	77.7	23.3	9.3
Souss-Massa	23	6.9	2.1
Guir-Ziz-Rheris	127.83	51.1	15.3
Draa	138.3	83.0	41.5
Saquiat El Hamra and Oued Eddahab	0	-	-
Total	2,523.6	1,583.5	861.7

Groundwater forecasts

In this scenario, despite water savings in irrigation, the use of substitute resources and government controls to contain or even significantly reduce water demand, the continuing decline in natural recharge under the effect of climate change will not give the aquifers time to adapt and their volumes to rebalance themselves. The overall volumes will remain significantly deficient and outflow through natural outlets will fall substantially.

Table 44 - Forecast groundwater balances with the potential impact of climate change

Basin	Sustainably exploitable groundwater resources			Groundwater demand			Balance		
	2010	2030	2050	2010	2030	2050	2010	2030	2050
LTCM	58.6	46.1	58.6	63.6	77.8	74.8	-5.0	-31.7	-16.2
Sebou	200.3	199.3	182.5	255.3	252.4	248.7	-55.1	-53.2	-66.2
Moulouya	678.4	642.6	622.5	769.4	762.1	771.3	-91.0	-119.5	-148.8
Bou Regreg and Chawia	53.7	47.3	35.2	106.6	101.2	92.6	-52.9	-53.8	-57.4
Oum Er Rbia	467.8	387.9	420.6	582.8	507.2	511.5	-115.1	-119.3	-91.0
Tensift	340.5	326.7	288.9	552.6	506.3	393.6	-212.1	-179.6	-104.7
Souss-Massa	345.0	320.2	264.5	641.4	508.8	384.0	-296.4	-188.5	-119.5
Guir-Ziz-Rheris	208.5	237.1	217.8	286.4	308.8	315.8	-77.9	-71.7	-98.0
Draa	174.3	185.3	176.2	220.0	230.1	233.9	-45.7	-44.8	-57.7
Saquiat El Hamra and Oued Eddahab	2.5	2.1	1.7	18.9	14.8	5.2	-16.4	-12.6	-3.6
Total	2,529.5	2,394.6	2,268.5	3,497.0	3,269.4	3,031.5	-967.6	-874.9	-763.1

2.2.3. Impact of climate change on water demand

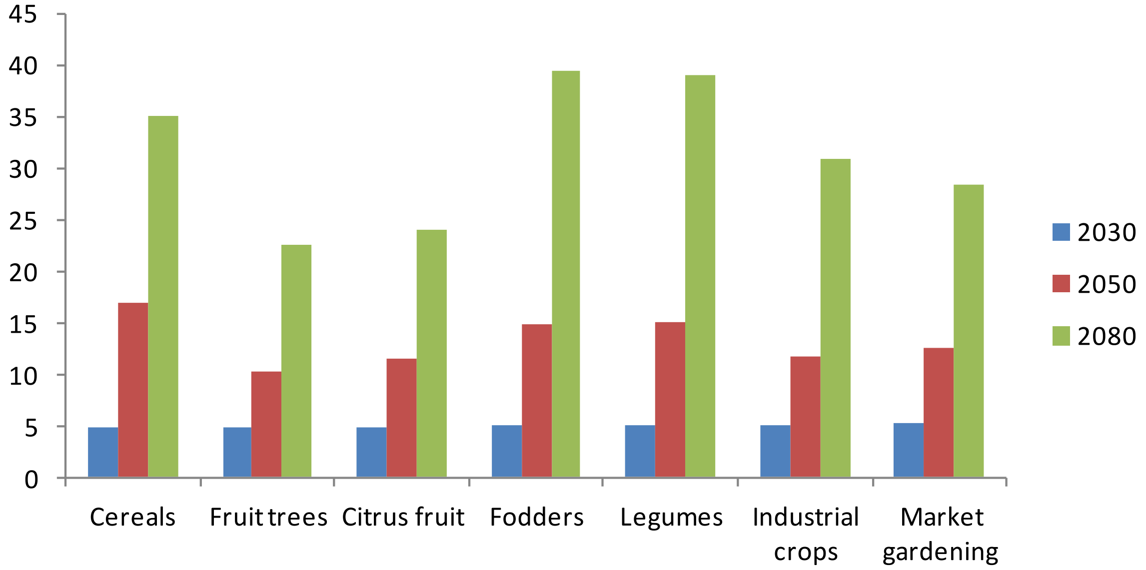
All plants are likely to experience an increase in evapotranspiration demand.

Plants' water needs are defined as the total volume of water (rain and/or irrigation) that a plant requires for optimal yield. Due to rising temperatures and the consequent increase in evapotranspiration, the water needs of all plants are set to increase.

Plants' water needs are an important indicator of the implications of climate change for farming practices. Many plants close all their stomata even with irrigation, because the atmospheric demand is too high. Once certain temperature thresholds are exceeded, it is possible that some currently cultivated crops may not adapt to future climate conditions, regardless of the amount of available irrigation water.

The study entitled *Changement climatique et agriculture: impact et implication climatique* ("Climate change and agriculture: impact and climate involvement") conducted by the World Bank, estimated the rate of increase of average water needs at around 5% by 2030, 10-15% by 2050 and 20-40% by 2080. These figures will be used in the present study.

Figure 24 -Rate of increase of average water needs



2.2.4. Projected water needs with climate change

It appears from the water balances summarised in the table below that most water basins will be in deficit. The overall deficit would be about 3,784 Mm³ in 2030 and 5,391 Mm³ in 2050:

Table 45 - Overall water balance taking into account the impact of climate change in Mm³

Basin	Exploited or exploitable surface water resources			Exploitable groundwater resources			Reuse			Desalination			Drinking water demand		Agricultural water demand		Environmental demand		Export/ Import		Balance	
	2010	2030	2050	2010	2030	2050	2010	2030	2050	2010	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
Loukkos	558	950	830	59	46	59	1	90	90		5	5	189	217	668	700					234	67
Moulouya	718	620	600	200	199	182	9	45	50		5	5	113	130	996	1,044	32	32			-272	-369
Sebou	2,400	1,872	1,600	678	642	622	18	120	130				298	344	3,208	3,361	63	63			-935	-1,416
Chawia dam	313	280	240	54	47	35		230	250		150	150	479	531	155	163			-120	-120	193	101
Oum Er Rbia	2,160	1,680	1,450	468	387	420	12	55	75		120	150	180	216	3,216	3,369	54	54	280	280	-1,488	-1,824
Tensift	100	132	115	341	326	289	16	50	60		30	35	140	165	965	1,011			-160	-160	-407	-517
Souss-Draa	385	312	270	345	320	265	2	75	75		150	150	127	148	1,541	1,615					-811	-1,003
Guir-Ziz-Rheris	139	600	520	174	185	176		20	20				48	55	1,041	1,090					-284	-429
Saquiat El Hamra	30	30	30	3	2	2		15	15	7	30	40	37	43	54	45					-14	-1
Total	6,803	6,476	5,655	2,322	2,154	2,050	58	700	765	7	490	535	1,615	1,850	11,844	12,398	149	149	0	0	-3,788	-5,392

VI. Economic perspective

Climate change is a reality in Morocco and its medium-term effects on the environment and on lifestyles are already visible. The main impacts of climate change on the water sector are:

- Increased water demand due to rising temperatures.
- Reduced rainfall over virtually all of Morocco.
- A reduction in exploitable water potential, identified in the PDAIREs, drafted in the 1980s. This decrease is the combined result of declining water resources and increased evaporation. It is estimated at 10 billion m³ per year.
- A decrease in hydropower potential from planned dams, estimated at 1,500 GWh per year.
- Changes in the available resource: alterations to river flows and groundwater recharge, degradation of water quality.
- Increased vulnerability of certain ecosystems because of rising temperatures and changes to rainfall distribution in time and space.
- Higher cost of access to water.
- Conflicts over use, etc.

The cost of these impacts is set to reach several billion dirhams. The areas most impacted would be those already affected by structural deficits.

These costs were estimated as follows:

- The cost of alternative solutions to compensate for the reduction in water availability. These solutions are identified in the adaptation strategy.
- The cost of alternatives to offset the reduction in energy production potential.
- The cost of the shortfall in agricultural land equipped for irrigation due to the reduced exploitable water volume. These costs are estimated based on the value created by the use of water on already equipped land.
- The cost of additional treatment.

1. Cost of alternative solutions

Alternatives to offset the reduction in water availability and hydroelectric power generation due to climate change will result in approximately 5 billion m³ of water and energy production of about 1,500 GWh per year. These projects relate to increased supply as well as management of the demand, including construction of a wind farm with a capacity of around 500 MW.

The overall cost of these projects is estimated at 70 billion dirhams (see table below).

Table 46 - Cost of alternatives to offset the reductions due to climate change

	Quantity (Mm³/yr)	Cost (billion dirhams)
Surface water exploited	1,700	15
Sea water desalination	500	12
Wastewater reuse	300	3
Surface water savings	2,500	40
Total	5,000	70

1.1. Water resources

1.1.1. Increased supply

Using surface water

Since independence, Morocco has adopted a targeted policy for controlling water resources through the construction of water infrastructure to ensure and secure the drinking water needs of urban and rural populations, develop irrigation of large agricultural areas and use its water potential in energy production.

Action plans were reviewed as part of the planning studies, to build major water infrastructure with the aim of providing the following services:

- Make use of all exploitable water, estimated at 20 billion m^3 per year, including 16 billion m^3 per year from surface water.
- Ensure hydroelectric production of around 3,500 GWh per year.

This infrastructure is largely completed. The cost of construction of hydraulic infrastructure for handling around 1.7 billion m^3 per year would be around 15 billion dirhams.

Using groundwater

These resources, which are currently over-exploited, are not a solution for increasing supply.

Artificial recharge of groundwater

The cost of recharge projects identified by the national strategy are estimated at 0.5 billion dirhams.

Wastewater reuse

This provides an opportunity to exploit an additional resource, estimated at 300 Mm^3 in 2030. The cost of this solution is estimated at 3 billion dirhams.

Sea water desalination

This is an alternative that was not originally developed in the PDAIREs. This solution could produce around 500 Mm^3 of usable fresh water by 2030. The cost of the proposed projects is evaluated at 12 billion dirhams, estimated on the basis of 9,000 dirhams per m^3 per day (approximately €900/m^3 per day).

1.1.2. Managing demand

Two major programmes are identified by the "Green Morocco Plan" and the National Water Resources Strategy to reduce water demand by around 1.1 billion m^3 by 2030.

- The drinking water conservation programme aims to recover nearly 120 Mm^3 by 2030. The overall cost of this project is estimated at 5 billion dirhams.
- The National Water Conservation Programme, which aims to increase the proportion of land irrigated with more efficient, water-saving techniques such as drip irrigation to nearly 50% of the total area equipped for irrigation within the next ten years. Special arrangements have been put in place to facilitate the implementation of this programme in terms of financial incentives and simplification of administrative procedures for awarding grants. The approximate overall cost of this programme is 37 billion dirhams.

1.2. Electricity generation

The alternative for offsetting the reduction in hydropower generation is the construction of a wind farm with a capacity of around 500 MW. The overall cost of this programme is estimated at 5 billion dirhams.

2. Shortfall

The decrease in water availability due to climate change is estimated at around 10 billion m^3 per year. This would be reduced to around 5 billion m^3 with the introduction of the identified alternatives. Irrigated agriculture will be affected by this significant reduction in water resources.

This sector is of vital importance for Morocco. It contributes about 7% of GDP and 50% of agricultural added value (this rate is higher during drought years). Irrigated agriculture, an important economic activity, is severely threatened by the growing lack of surface water and the unbridled exploitation of groundwater.

Average productivity is currently 1.6 dirhams per m^3. This productivity is set to be 5 dirhams per m^3 after completion of the Green Morocco Plan. The cost of the shortfall in the amount of water lost and not compensated by the implementation of alternative solutions would be 15 billion dirhams per year.

The climate change adaptation strategy has adopted high energy-consuming alternatives. This consumption would result in an additional annual cost of around 3.5 to 4 billion dirhams.

VII. Appendices

Appendix 1: Irrigation water supplies from all dams

Year	Water supply (Mm³)
1980-1981	3,266.2
1981-1982	2,091.7
1982-1983	2,204.3
1983-1984	1,272.5
1984-1985	1,778.0
1985-1986	2,038.6
1986-1987	2,856.9
1987-1988	2,975.1
1988-1989	3,158.0
1989-1990	3,322.8
1990-1991	3,414.6
1991-1992	3,622.8
1992-1993	2,726.6
1993-1994	2,733.4
1994-1995	2,709.4
1995-1996	2,648.7
1996-1997	3,831.4
1997-1998	3,385.1
1998-1999	3,409.2
1999-2000	3,147.7
2000-2001	2,728.2
2001-2002	2,264.6
2002-2003	2,571.1
2003-2004	2,995.9
2004-2005	3,649.8
2005-2006	2,596.8
Average supply	2,823.1
Allocation set aside by PDAIREs	7,281.7
Allocation set aside by PDAIREs adjusted to take equipment into account	,547.7

Appendix 2: Changes in drinking water and industrial water demand in Mm³ per year

Water Basin	Environment	2010	2020	2030	2050
Moulouya, Figuig-Kert-Isly-Kiss	Urban	66	75	89	98
	Rural	11	15	24	33
	Total	77	90	113	130
Loukkos, Tangiers and Mediterranean coastlines	Urban	108	133	162	179
	Rural	11	16	27	39
	Total	120	149	189	217
Sebou	Urban	179	199	237	258
	Rural	28	38	61	85
	Total	206	237	298	344
Bou Regreg and Chawia	Urban	322	382	451	491
	Rural	12	17	28	40
	Total	334	399	479	531
Oum Er Rbia and El Jadida-Safi	Urban	85	98	117	128
	Rural	30	40	64	88
	Total	115	139	181	216
Tensift and Ksob-Igouzoulen	Urban	72	87	106	117
	Rural	16	22	35	48
	Total	88	110	142	165
Souss Massa-Draa	Urban	58	74	96	110
	Rural	15	21	31	38
	Total	73	96	127	148
Guir-Ziz-Rheris	Urban	18	21	26	28
	Rural	12	16	22	27
	Total	29	37	48	55
Saquait El Hamra and Oued Eddahab	Urban	18	26	33	37
	Rural	2	3	5	6
	Total	20	29	37	43
Total	Urban	926	1,096	1,318	1,446
	Rural	137	189	297	404
	Total	1,063	1,285	1,615	1,850

Appendix 3: Changes in water demand of large-scale hydropower areas depending on the implementation of the Moroccan National irrigation water-saving programme (PNEEI)

Area	Water demand according to PDAIRE (Mm³/yr)		Water demand according to PNEEI 2010			Water demand according to PNEEI 2030		
	2020	End of 2008	Area converted to drip irrigation (ha)	Water savings per plot (Mm³/yr)	Water demand (Mm³/yr)	Area converted to drip irrigation (ha)	Water savings per lot	Water demand (Mm³/yr)
Doukkala Low service High service	1,104 550 554	853 550 303	10,534	26.2	827	76,599	191	662
Tadla Beni Moussa Beni Amir	1,212 740 472	1,212 740 472	8,000	26.7	1,185	88,742	296	916
Houz Upstream Tessaout Downstream Tessaout Central Houz	1,370 260 235 710	1,043 260 235 343	8,902	19.5	1,023	80,603	177	866
Gharb Beht PTI STI TTI Zrar	2,278 229 352 627 1,017 54	1,083 229 352 502 - -	6,279	18	1,065	65,699	188	895
Moulouya	717	717	8,821	24.6	692	51,205	143	574
Loukkos	381	381	4,078	13.6	323	18,949	63	274
Souss-Massa Upstream Souss Issen Massa and Tassila	164 52 37 75	164 52 37 75	4,585	5.7	158	9,802	12	152
Tafilalet Mid-Ziz Tafilalet Plain	180 70 110	180 70 110	416	0.8	179	2,000	4	176
Draa	376	376	200	0.6	375	1,500	4	372
Total	7,783	5,965	51,815	135	5,829	395,099	1,078	887

Appendix 4: Water demand of extended irrigation

Areas	Surface area (ha)	Water demand (Mm^3/yr)
E3- E5-Z6	21,783	181
Z3-Z4	25,818	202
Z1-Z2-N10	3,500	343
Z5-extension Beht Zrar	23,868	153
Lower Loukkos	16,000	115
Dar Krofa	15,000	100
Total	137,470	1,094

Appendix 5: Comparison of water supply

Dam	Long series		Short series		Median series	
	Definition	Water supply (Mm³)	Definition	Water supply (Mm³)	Definition	Water supply (Mm³)
Dar Khrofa	1945-2006	201.5	1979-2006	156.0	1961-1990	217.9
Al Wahda	1939-2002	2,724.1	1979-2002	1,841.9	1961-1990	2,723.8
9 April	1945-1999	75.9	1979-1999	50.8	1961-1990	74.8
Hassan Addakhil	1940-1999	146.8	1979-1999	94.6	1961-1990	138.7
Allal El Fassi	1939-1999	596.9	1979-1999	337.4	1961-1990	582.9
Aoulouz	1935-1999	179.7	1979-1999	150.2	1961-1990	212.0
Ibn Battouta	1945-1999	52.3	1979-1999	39.4	1961-1990	45.2
Hassan 1	1939-1999	277.7	1979-1999	188.8	1961-1990	286.4
Idriss 1	1939-1999	556.5	1979-1999	260.5	1961-1990	572.3
El Kansera	1939-1999	365.2	1979-1999	200.6	1961-1990	366.6
Mohammed Ben Abdelkrim Al Khattabi	1945-1999	48.2	1979-1999	19.9	1961-1990	53.9
Oued El Makhazine	1940-1999	751.3	1979-1999	484.7	1961-1990	677.9
Mansour Eddahbi	1940-1999	427.3	1979-1999	407.1	1961-1990	453.2
Mohammed V	1939-1999	837.7	1979-1999	563.7	1961-1990	817.4
Abdelmoumen	1936-1999	81.5	1979-1999	75.9	1961-1990	97.6
Moulay Youssef	1939-1999	287.3	1979-1999	232.5	1961-1990	302.7
Nakhla	1945-1999	55.1	1979-1999	47.6	1961-1990	61.9
Bin El Ouidane	1939-1999	1,049.7	1979-1999	642.4	1961-1990	1,082.9
Smir	1945-1999	27.1	1979-1999	24.0	1961-1990	27.7
Lalla Takerkoust	1935-1999	182.3	1979-1999	188.9	1961-1990	205.5
Sidi Mohammed Ben Abdellah	1939-1999	667.6	1979-1999	403.4	1961-1990	671.4
Youssef Ben Tachafine	1939-1999	134.5	1979-1999	89.9	1961-1990	137.7
Al Massira	1940-1999	1,798.3	1979-1999	1,137.6	1961-1990	019.1

Appendix 6: Energy consumption by the water sector

Changes in the volumes pumped in large-scale hydropower areas, managed by the Moroccan Regional Agricultural Offices (ORMVA) (m³)

ORMVA	2004	2005	2006	2007	2008	Mean 2004-08
Moulouya	46,586,040	51,737,000	48,640,272	39,725,000	50,389,297	47,415,522
Gharb	273,340,000	545,850,000	354,167,970	571,326,410	403,525,150	429,641,906
Doukkala	338,341,000	340,399,000	271,956,000	228,900,000	194,701,828	274,859,566
Tadla	7,573,000	9,068,000	6,982,000	7,800,000	7,188,066	7,722,213
Ouarzazate	2,270,000	2,483,000	2,253,000	2,500,000	2,242,296	2,349,659
Souss-Massa	88,399,667	93,258,000	94,341,500	68,750,000	44,990,000	77,947,833
Loukkos	151,805,714	171,860,675	143,350,494	108,405,195	132,931,094	141,670,634
Total	908,315,420	1,214,655,675	921,691,235	1,027,406,605	835,967,731	981,607,333

Changes in energy consumption in large-scale hydropower areas, for each ORMVA (m³)

ORMVA	2004	2005	2006	2007	2008	Mean 2004-08
Moulouya	26,620,594	29,564,000	27,794,441	22,700,000	28,793,884	27,094,584
Gharb	27,334,000	54,585,000	35,416,797	57,132,641	40,352,515	42,964,191
Doukkala	54,400,000	53,135,000	41,707,000	34,200,000	28,543,108	42,397,022
Tadla	1,102,000	1,259,000	966,000	1,000,000	990,067	1,063,413
Ouarzazate	733,000	782,000	751,000	600,000	775,141	728,228
Souss-Massa	48,218,000	50,868,000	51,459,000	37,500,000	24,540,000	42,517,000
Loukkos	78,980,000	89,414,000	74,581,000	56,400,000	69,160,096	73,707,019
Total	237,387,594	279,607,000	232,675,238	209,532,641	193,154,811	230,471,457

Estimated energy requirements for irrigation from groundwater

Over the past twenty years, continued declines in water levels have been observed in almost all aquifers in the country, reaching alarming values, sometimes exceeding 2 metres per year. These groundwater levels will evolve in the same direction as the water balances. They will continue to decline. Between now and 2030, the current downturn will be more or less steady, with an easing-off in some locations. Between 2030 and 2050, the decline will slow and Morocco will move closer to balance by 2050.

The following table summarises the decreases identified by basin.

Basin	Mean depths identified (m)	Current decline (m/yr)	Mean drop in groundwater levels not taking climate change into account	
			Between 2010 and 2030 (m)	Between 2010 and 2030 (m)
Loukkos	15	Stable	2	1
Moulouya	25	0.8	10	5
Sebou	100	0.5	10	5
Bou Regreg	15	0.7	10	5
Oum Er Rbia	35	0.6	8	4
Tensift	35	1.5	15	8
Souss-Massa	60	1.5	15	10
Guir-Ziz-Rheris	15	0.2	4	2
Draa	15	0.3	5	3
Saquiat El Hamra and Oued Eddahab	60	0.1	2	1

The energy required for pumping groundwater has been estimated from the volume of water abstracted from groundwater and from depths and changes, assuming a pumping efficiency of 35%, derived from the literature. Hammami and Yechi found that, in the Tadla area, the maximum efficiency of electric pumping stations is 0.59, while the overall efficiency of diesel-powered equipment does not exceed 0.17.

Since the average depth per basin is hard to estimate, the work was conducted using ranges, which gave energy values within fairly broad ranges. Using this method of calculation, the energy required to pump groundwater is roughly, in a context of climate stability, around 600 GWh per year.

The following table summarises the energy required for groundwater abstraction.

Year	Energy for pumping groundwater (GWh) per year in a context of climate stability
2010	550
2030	650
2050	650

Water estimate for extensions to irrigated land

According to the PDAIREs that are currently in progress, the extensions to irrigated land are assessed at around 140,500 ha, of which 106,500 ha are located in the Sebou basin. The table below presents the main characteristics of these agricultural areas.

The assumption for calculating energy needs is:

Capacity P1 = p . g . Q .H / K1 where:

- p: density of water, equal to 1 Kg/L
- g: gravitational pull, taken as 9.8L/Kg
- Q: water flow in L/s
- H: effective head, in m
- K1: efficiency considered equal to 0.70

Area	Surface area (ha)	Water demand (Mm^3/yr)	Head (m)	Energy need (GWh)
Z5, East Beht, Zrar	23,870	153	60	37
Z1, Z2, N10	35,000	343	30	40.5
Z3, Z4	25,818	202	30	23.5
E5, Z6, E3	21,783	181	30	22
Dar Khrofa Area	16,000	100	90	38
Lower Loukkos Area	18,000	120	140	68
Total	140,470	1,100	-	230

Estimate of energy needs for water transfer

To mitigate the alarming deficit currently observed in the Oum Er Rbia basin and support the socioeconomic development of the Bou Regreg, Oum Er Rbia and Tensift basins, the National Water Resources Strategy has recommended a project that would transfer water from the Sebou, Loukkos and Oued Laou basins. This project, which will be implemented in two phases, aims to transfer a water volume of about 800 Mm^3 per year:

- First phase: 400 Mm^3 per year from the Sebou basin.
- Second phase: 400 Mm^3 per year from the Loukkos and Laou river basins.

Several solutions were studied, differing mainly in the course and volume of transferable water. The main features of this project can be summarised as follows:

Solution	Cost of works (unit)	Pumping station		Length (km)			
		Total Dynamic Head (m)	Number	Channels	Tunnels	Pipes	Total
T1	36.6	596	8	145.5	191.2	80	416.6
T1V	33.65	450	8	171.8	150	73	394
T2	32.35	592	8	197	191	78	446
T2V	32.01	450	8	250	150	73	473
T2b	37.7	596	8	221	191	75	487
T2bV	34.28	450	8	247	150	73	470

The assumptions used in calculating the energy consumption of the water transfer project can be summarised as follows:

- Pump efficiency: 0.7
- Transferable volume: 800 Mm^3/yr
- Head: 450 m

With these assumptions, energy consumption would be approximately 1,400 GWh, or 1.8 kWh/m^3.

Estimate of energy needs of the drinking water sector

ONEP

Indicator	2005	2006	2007	2008
Volume of water produced (Mm^3)	753	767	778	794
Energy consumption (GWh)	452	468	500	516
Ratio (kWh/m^3)	0.6	0.61	0.64	0.65

Oum Er Rbia company

Indicator	2005	2006	2007	2008
Volume of water produced (Mm^3)	60	60	60	60
Energy consumption (GWh)	35	35	35	35
Ratio (kWh/m^3)	0.58	0.58	0.58	0.58

State-owned companies 2006

Indicator	Volume of water produced (Mm^3)	Energy consumption (GWh)	Ratio (kWh/m^3)
RADEEF	17.306	8.51	0.492
RADEM	25.43	0	0
RAK	15.954	8.35	0.523
RADEEJ	2.401	2.63	1.095
RADEEL	1.124	0.85	0.75
RADES	0.693	0.477	0.685
RADEO	12.688	8.92	0.704
RADEEC	0.515	0.39	0.748
RADEET	1.409	2.20	1.568
RADEETA	7.173	3.61	0.504

State-owned companies 2007

Indicator	Volume of water produced (Mm³)	Energy consumption (GWh)	Ratio (kWh/m³)
RADEEF	16.675	8.53	0.512
RADEM	20.83	0	0
RAK	14.942	8.03	0.538
RADEEJ	2.455	3.10	1.264
RADEEL	1.222	0.88	0.723
RADES	0.711	0.5	0.714
RADEO	11.255	8.30	0.7038
RADEEC	0.471	0.32	0.662
RADEET	1.587	2.15	1.357
RADEETA	5.675	3.77	0.666

State-owned companies 2008

Indicator	Volume of water produced (Mm³)	Energy consumption (GWh)	Ratio (kWh/m³)
RADEEF	17.598	8.12	0.461
RADEM	15.28	0	0
RAK	13.657	7.4	0.542
RADEEJ	2.289	2.64	1.154
RADEEL	1.109	0.62	0.56
RADES	0.669	0.511	0.765
RADEO	10.783	8.21	0.762
RADEEC	0.469	0.477	1.019
RADEET	1.139	2.15	1.891
RADEETA	5.931	3.28	0.553

Appendix 7: Hydroelectric power generation

Year	Installed capacity (MW)	Energy production (GWh)
1980	615.4	1,515
1981	615.4	1,024
1982	615.4	572
1983	615.4	481
1984	615.4	366
1985	615.4	486
1986	615.4	643
1987	615.4	825
1988	615.4	936
1989	615.4	1,157
1990	615.4	1,219
1991	615.4	1,266
1992	922.4	981
1993	922.4	454
1994	922.4	855
1995	922.4	605
1996	922.4	1,938
1997	1,167	2,062
1998	1,167	1,759
1999	1,167	817
2000	1,167	705
2001	1,167	862
2002	1,265	842
2003	1,265	1,450
2004	1,498	1,600
2005	1,729	958
2006	1,729	982
2007	1,729	902
2008	1,729	916.2

Appendix 8: Relationships between rain deficit and runoff deficit

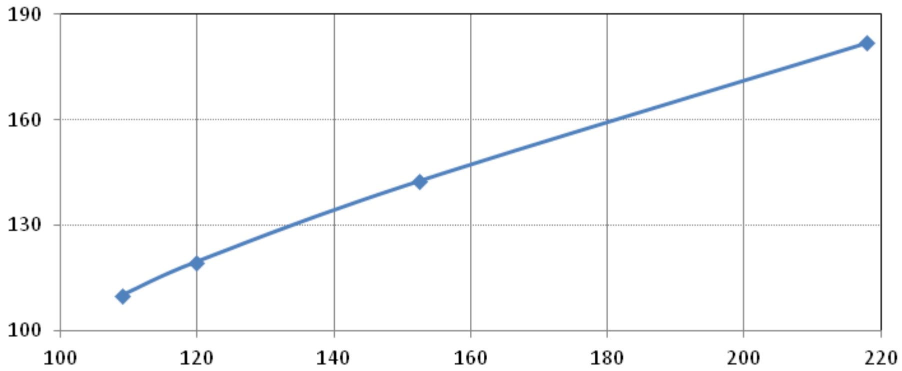
Basin	Year	Rain deficit (%)	Runoff deficit (%)	RunDef/RainDef Ratio	Source
Upper Sebou	2006-2007	32.23	63	2	Situation hydrologique (Hydrological situation document)
Ouergha	2006-2007	33.41	76	2	Situation hydrologique
Beht	2006-2007	33.41	76	2	Situation hydrologique
Inaouene	2006-2007	37.5	86	2	Situation hydrologique
Massa	2006-2007	60	91	1.5	Situation hydrologique
Issen	2006-2007	55	91	2	Situation hydrologique
Issen	2007-2008	62	88	1.4	
Massa	2007-2008	40	88	2	
Morocco	1991-1992	9.6	44	4	*Un siècle d'observations météorologiques : Sécheresse et gestion de l'eau au Maroc* (A century of meteorological observations: Drought and water management in Morocco)
Morocco	1992-1993	38.3	75	2	*Un siècle d'observations météorologiques : Sécheresse et gestion de l'eau au Maroc*
Morocco	1993-1994	11.8	25	2	*Un siècle d'observations météorologiques : Sécheresse et gestion de l'eau au Maroc*
Morocco	1994-1995	36.5	73	2	*Un siècle d'observations météorologiques : Sécheresse et gestion de l'eau au Maroc*

Appendix 9: Simulations of the hydraulic performance of some dams

Dar Khrofa Dam

Scenario	1961-1990 series	Series reduced by 30%	Series reduced by 45%	Series reduced by 50%
Supply (Mm³/yr)	217.9	152.5	119.8	109.0
Regulated volume (Mm³/yr)	181.9	142.6	119.5	110.0
Maximum deficit (%)	50%	49%	49%	50%
Average deficit (%)	11%	10%	9%	9%
Failure rate (%)	20%	20%	20%	20%
Hydro-electric production (GWh)	0.0	0.0	0.0	0.0
Reduction in supply	-	30%	45%	50%
Reduction in regulated volume	-	22%	34%	40%
Reduction in hydro-electric production	-	-	-	-

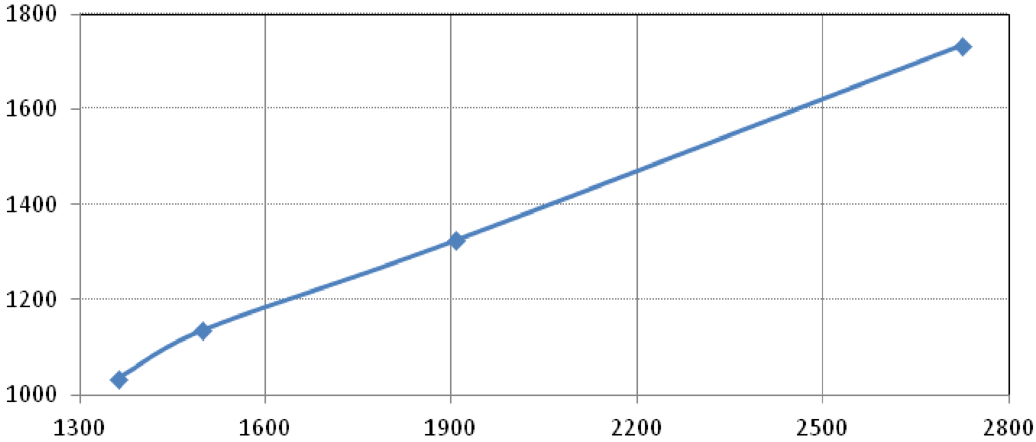
Volume adjusted from the inputs



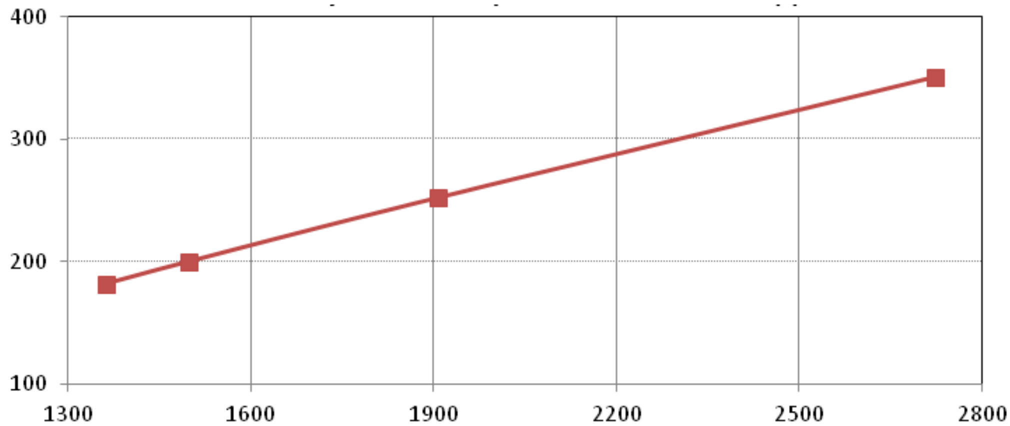
Al Wahda Dam

Scenario	1961-1990 series	Series reduced by 30%	Series reduced by 45%	Series reduced by 50%
Supply (Mm³/yr)	2,723.8	1,906.6	1,498.2	1,362.2
Regulated volume (Mm³/yr)	1,733.7	1,323.8	1,135.0	1,033.7
Maximum deficit (%)	50%	44%	50%	50%
Average deficit (%)	6%	5%	9%	9%
Failure rate (%)	20%	20%	20%	17%
Hydro-electric production (GWh)	351.0	252.1	200.0	181.9
Reduction in supply	-	30%	45%	50%
Reduction in regulated volume	-	24%	35%	40%
Reduction in hydro-electric production	-	28%	43%	48%

Volume adjusted frm the inputs

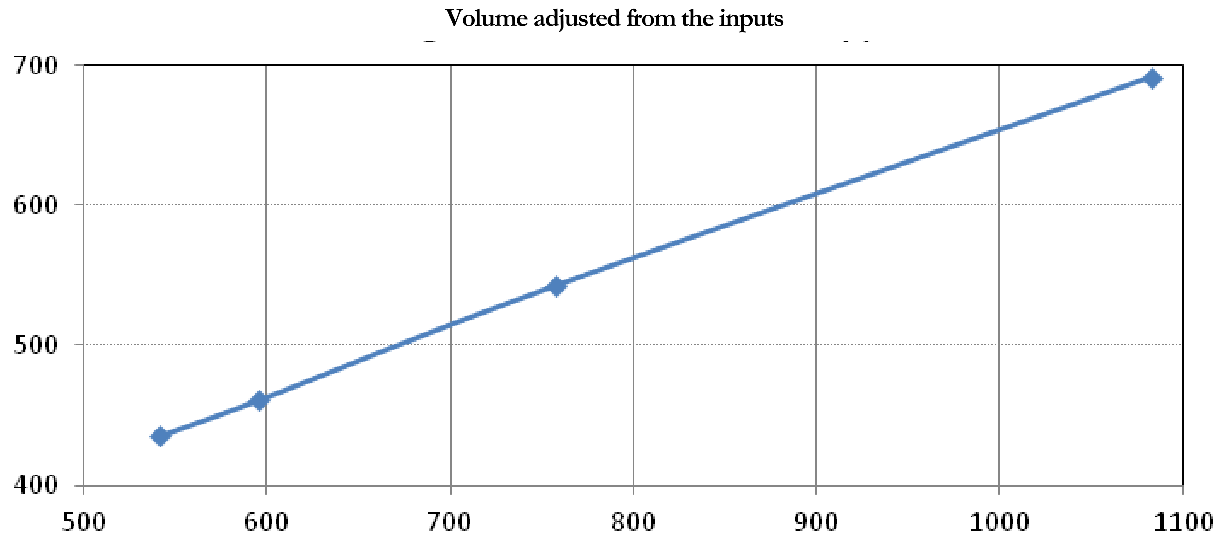


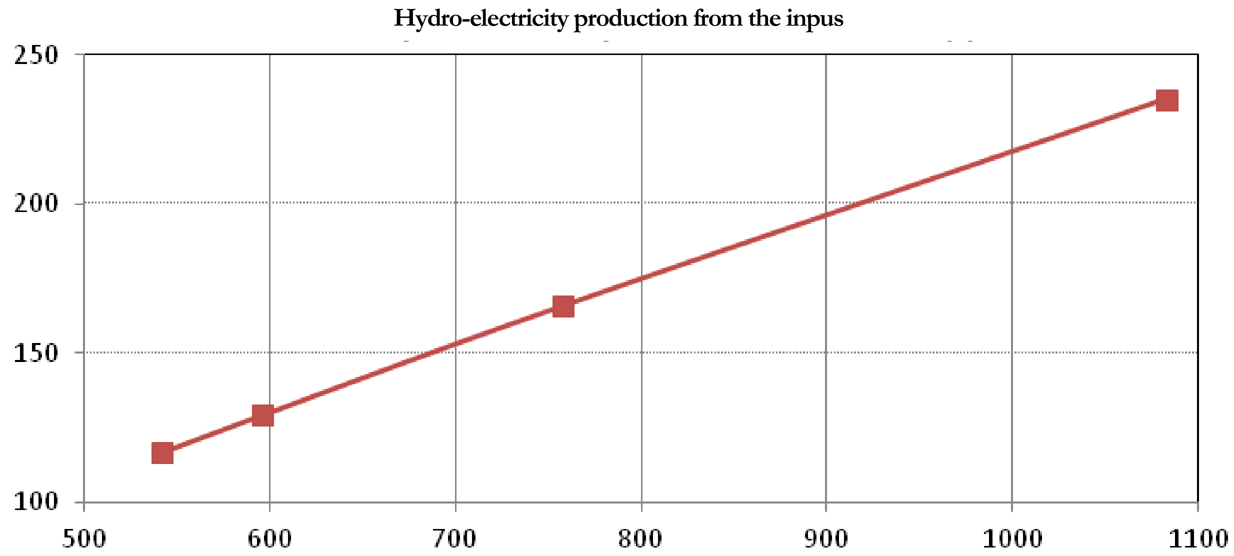
Hydro-electricity production from the inputs



Bin El Ouidane Dam

Scenario	1961-1990 series	Series reduced by 30%	Series reduced by 45%	Series reduced by 50%
Supply (Mm³/yr)	1,082.9	758.0	595.6	541.5
Regulated volume (Mm³/yr)	691.0	542.6	460.7	435.1
Maximum deficit (%)	50%	50%	50%	50%
Average deficit (%)	7%	10%	8%	8%
Failure rate (%)	20%	20%	20%	20%
Hydro-electric production (GWh)	235.2	166.0	129.2	116.7
Reduction in supply	-	30%	45%	50%
Reduction in regulated volume	-	21%	33%	37%
Reduction in hydro-electric production	-	29%	45%	50%


Volume adjusted from the inputs
700
600
500
400
500
600
700
800
900
1000
1100


Hydro-electricity production from the inpus
250
200
150
100
500
600
700
800
900
1000
1100

Appendix 10: Actual hydroelectric production compared to expected production

Year	Expected production (GWh)	Actual production (GWh)
1993	1,962	454.065
1994	1,962	855.064
1995	1,962	618.123
1996	2,352	1,965.492
1997	2,352	2,091.699
1998	2,352	1,785.351
1999	2,382	833.874
2000	2,382	719.863
2001	2,582	872.839
2002	2,616	852.231
2003	2,616	1,454.012

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VIII. Table of illustrations

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Tables