Journal of Energy in Southern Africa 22(3): 8–15
DOI: http://dx.doi.org/10.17159/2413-3051/2011/v22i3a3217

The challenges and potential options to meet the peak electricity demand in Mauritius

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Abstract
This paper reviews the current challenges facing Mauritius in terms of meeting peak electricity demand. As a fast-developing island-economy with a very high population density, this is a crucial issue. The more so that it imports 80% of its energy requirements in terms of fossil fuels, relies significantly on tourism and needs to protect its fragile ecosystems. The nature of the peak electricity demand and its evolution is firstly analysed. Reference is made to past scenarios for electricity supply, the obstacles to their implementation and their relevance in terms of sustainability. The forecasts underpinning the latter scenarios are found to be over-estimated. Demand-Side Management projects are discussed and their potential to promote an alternative scenario based on revised forecasts are discussed. Hence a new Maurice Ile Durable (Mauritius Sustainable Island, MID) scenario is proposed in view of stabilising the peak demand, reducing the rate of increase of total electricity demand and making the capacity margin positive. The newly-devised scenario is not only more sustainable but also addresses several political and socio-economic issues to bring holistic win-win solutions. Institutional and regulatory reforms as well as a relevant Business Framework are also important in order to meet the challenges of MID. The new scenario relies only on existing technology with an excellent track-record and provides the transition to a more sustainable future.

Keywords: peak demand, electricity, Mauritius, demand-side management, sustainability

Acronyms

CEB Central Electricity Board
CSO Central Statistics Office
DSM Demand-side management
DST: Daylight Saving Time
GDP: Gross development product
IPP: Independent power producer
OEP: Outline Energy Policy
MID: Maurice Ile Durable (Mauritius Sustainable Island) project
SIPP: Small ondependent power producer

1. Introduction

As a fast-developing economy, Mauritius has to meet increasing energy demand, particularly in terms of peak electricity as shown in Figure 1.

In 2009, the peak demand attained 389 MW (Hansard, 2009a), representing an increase of 17 % over the last 5 years. The peak occurs during summer with the difference in the maximum demands between summer and winter increasing from 25 MW in 2004 to 40 MW in 2008. This difference is due to the massive use of ventilation, air-conditioning and refrigeration during the summer months, particularly during the recent years that have been marked with high average temperatures and the construction boom in the residential, tourism and services sectors.

It has been demonstrated that the correlation coefficient between peak demand and atmospheric temperature is above 0.9 (Badurally et al., 2009). This is illustrated for 2008 in Figure 2. It is to be noted that both average humidity and number of hours of sunshine increase in summer and, hence, tend to increase the peak demand.

1.1 Supply

Figure 3 illustrates how the peak demand is typically met at the supply end. From the bottom of the chart upwards, electricity is generated from base-load coal or bagasse power plants owned by independent power producers or IPPs (CTDS, Beau-Champ, FUEL, CTSAV and CTBV). The other plants are owned by the Central Electricity Board (CEB), the sole distributor and supplier of grid power. It is to be noted that the CEB generates power from hydro (including Champagne), fuel oil (Fort George, St Louis and Fort Victoria) and

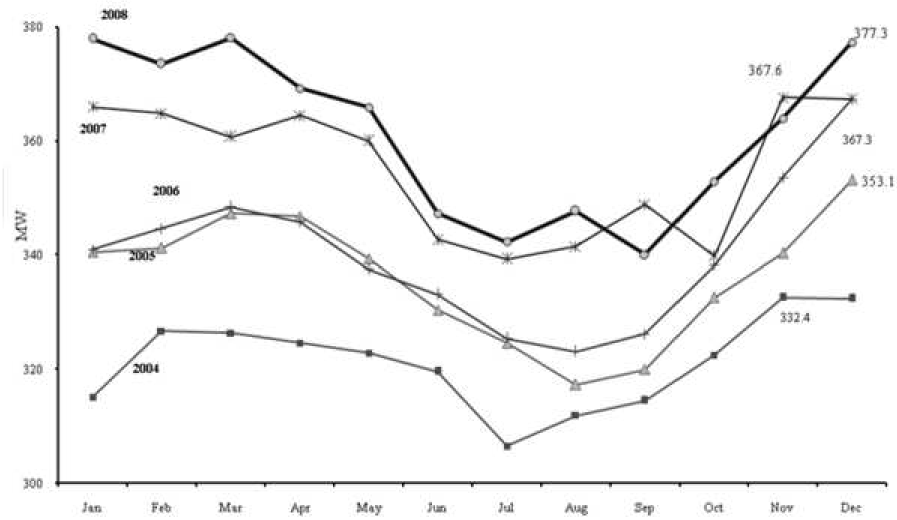

Figure 1: Peak electricity demand from 2004 to 2008
Source: CSO (2008a)

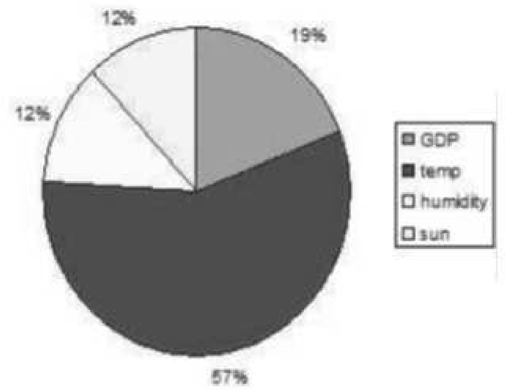

Figure 2. Impact of GDP, temperature, humidity and number of hours of sunshine on peak electricity demand for 2008
Source: Badurally et al. (2009)

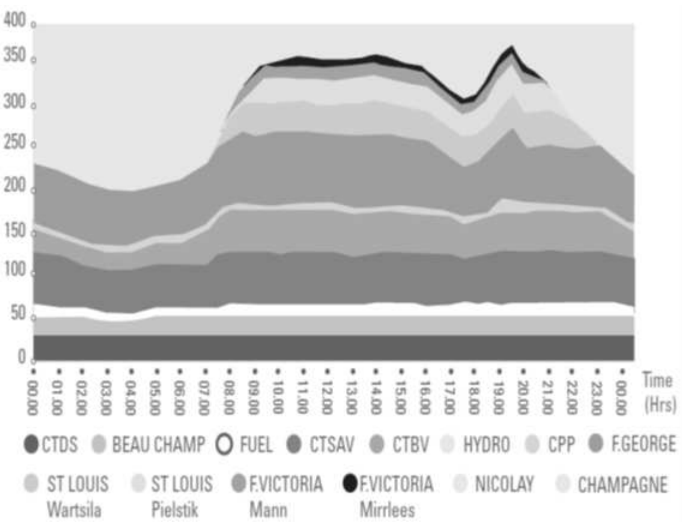

Figure 3. Typical load supply curve of electricity from power plants (listed from bottom first)
Source: Kassim (2010)

kerosene (Nicolay). The latter, using a 76 MW gas turbine, is normally reserved for emergency purposes and is occasionally run for peaking only, given that its cost is at least four-fold higher.

It is to be noted that the distribution losses amount to about 10% (CEB, 2008). The total installed capacity is now 504 MW, including allowance for maintenance, repairs and a 10% spinning reserve (Hansard, 2009b). Currently more than 60% of electricity is generated by the IPPs, the CEB being responsible mostly for the semi-base and peak load power supply areas. Much of the CEB capacity is not fully exploited because of binding contracts with IPPs to give priority to their base-load supply and because of the dependence on rainfall for hydropower.

It is to be noted that fuel oil and kerosene used by CEB are more costly compared to coal, and even more expensive when compared to bagasse at market prices. The latter is fully utilised but the efficiency of its conversion can be improved by the introduction of high pressure cogeneration plants. Together with the use of other biomasses like cane tops and leaves, at least three times more electricity can be produced using currently available technology (Autrey et al., 2006). This will ensure also a stronger substitution of coal, used during the inter-crop season, by renewable biomass. Figure 4 shows the energy mix for power generation for 2008. The wind power indicated is negligible and refers to the island to Rodrigues.

1.2 Demand-side management

In 2009, the amount of power generated was almost the same as in 2008. Moreover, the peak demand moved to the morning during the summer

Table 1: Power generation by source in 2008
Source: CSO (2008b)

Source of energy	*GWh*	*%*
Primary energy	108.4	4.2
Hydro (renewable energy)	108.0	4.2
Wind (renewable energy)	0.4	0.0
Secondary energy	2 448.8	95.8
Gas turbine (kerosene)	6.6	0.3
Diesel & fuel oil	827.1	32.3
Coal	1 128.7	44.1
Bagasse (renewable energy)	486.4	19.0
Total	**2 557.2**	**100.0**
Of which: renewable energy (hydro, wind & bagasse)	594.8	23.3

months, instead of occurring in the evening as usually observed in the past. In fact, a plateau of about 380 MW was recorded in the morning and early afternoon during hot summer weekdays (Assirvaden, 2010). This confirms the trend noted recently with the massive use of ventilation, air-conditioning and refrigeration in residential, touristic, commercial and office buildings.

The stabilisation of the demand for electricity in 2009, together with a peak demand growth of only 2%, were the direct results of Demand-Side Management (DSM) measures coupled with a slowing of the economic growth to 2.5% in 2009. The influence of GDP on peak electricity demand has already been evoked above.

There were four DSM measures that interacted to achieve the situation in 2009.

i) Some 1 million Compact Fluorescent Lamps (CFLs) were distributed at subsidized costs to the general public from August 2008 to early 2009. As a result, the Government estimates that an average saving of 14 MW has been achieved during the evening peak (Hansard, 2009c). Studies conducted at the University of Mauritius on Energy Management in the residential sector indicates that the impact of CFLs was probably even more significant, of up to 25 MW (Bahadoor, 2009; Ramnarain, 2009).

ii) More than 25 000 solar water heaters were installed in 2008 with the introduction of a direct subsidy of Rs 10 000 (approx. USD 300) per unit. This has led to a reduced utilisation of electric water heaters. It is reasonable to estimate an average reduction of about 5 MW on the evening peak resulting from the latter measure.

Iii) The Government introduced a national energy-saving campaign under the Maurice Ile Durable (MID) project focusing on all sectors. Sensitization on peak demand reduction was the focus of a sustained campaign. Although the last increase in electricity prices was in 2007, it is understood that there is a growing awareness on DSM resulting in an effective drop in power demand, particularly in the evening. It is difficult to estimate its exact impact but it is possible that it may reach as much as 15 MW occasionally, comparable to the drop noted immediately after sharp rises in prices like in 2007.

iv) As a pilot project, Daylight Saving Time (DST) was adopted from October 2008 to March 2009. The project has now been dropped primarily because of public outcry related to social and cultural disruption, but also because the expected energy savings were not achieved. The summer of 2009-2010 had ended without DST and there is no evidence to prove that the pilot project had a significant positive impact. Above all, since December 2008, but more regularly ever after, the maximum peak electricity demand has been occurring in the morning during weekdays in summer. Nevertheless, it cannot be overlooked that DST did reduce the evening peak. However, the actual amount may be much less than the 15 MW average that was been put forward by the CEB (Elahee, 2008).

2. Forecasts

In the light of the above, electricity demand forecasts were revised slightly downwards in 2009 (Hansard, 2009d). Figures 4, 5 and 6 depict the initial forecasted demands as from 2003 and the actual figures up to 2008. As noted, the demand for 2009 is now known to be very close to that of 2008.

The obvious deduction from the graphs is that the forecasted CEB figures are well above actual values. The difference for 2010 stands at 50 MW between the CEB forecast and the trend based on the recent values recorded. In 2015, this gap increases to 100 MW. Even considering the latest forecasted values made public in 2009, the difference is not less (Hansard, 2009d). The DSM impact discussed amounting to a total average drop of about 25 MW had not been considered in the CEB forecasts in 2003 and in 2007.

It can be argued that under the combined effect (1) of sustained DSM to bring a total reduction of peak demand of 30 MW by 2012 and (2) of moderate economic growth of between 2 and 5 % of GDP over the same period, the peak electricity demand is likely to stabilise at about 400 MW. This is close to the extrapolated trend shown in Figure 6.

Similarly, Figure 5 depicts a more realistic trend if DSM is pursued, along with moderate economic growth as is now predicted to happen over the next few years by most specialists (EconomyWatch, 2010). In any event, one of the key objectives of DSM is to decouple GDP and energy requirement. This is made easier by the ongoing transformations in the economy of Mauritius as the services sector grows and diversifies at the expense of the

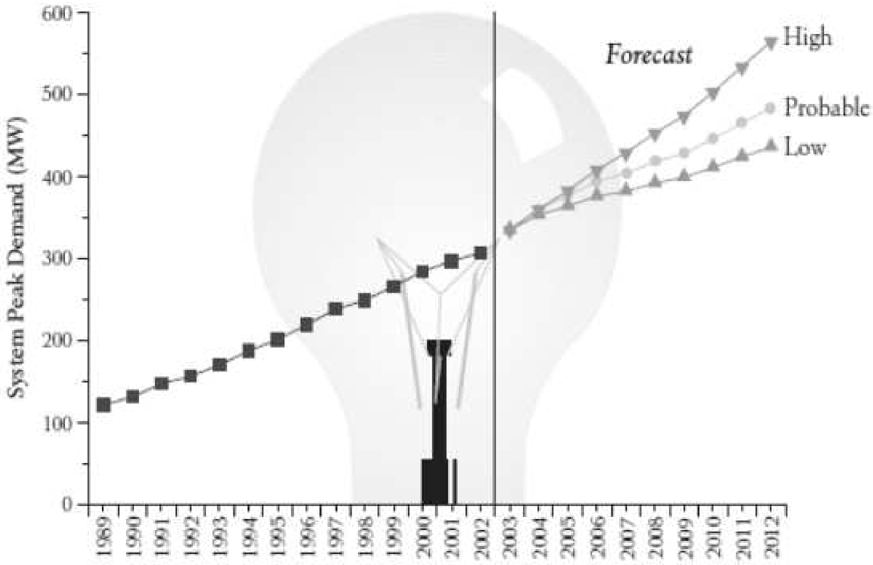

Figure 4: Forecast of peak electricity demand made in 2003
Source: CEB (2003)

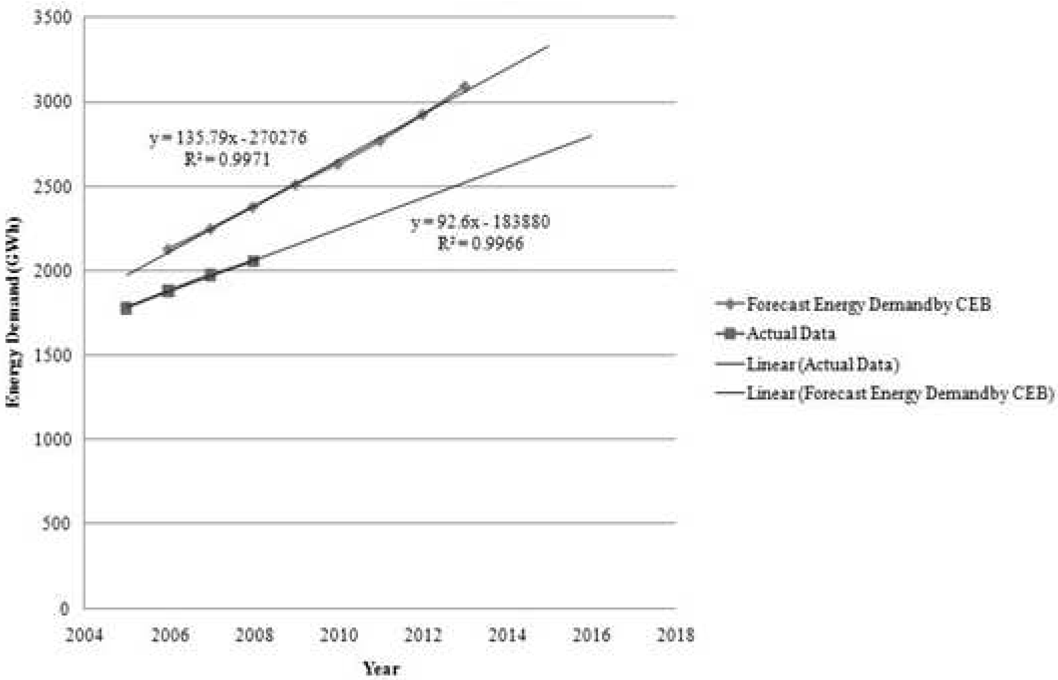

Figure 5. Forecast of total electricity demand and comparison with actual
Source: CEB (2007a)

energy-intense manufacturing and agricultural sectors.

DSM can be the key to meeting the energy demands, including morning peaks during weekdays in summer, provided the following specific orientations are urgently adopted:

i) The Energy Management Office to facilitate DSM in all sectors, already announced by the Government in the 2010 Budget, should be set up without delay (MoF, 2009).
ii) The Energy Efficiency Act under preparation and the Building Code should be promulgated to ensure energy efficient practices related to appliances and buildings respectively.
iii) Solar-water heating, including in air-conditioning and refrigeration, sustainable design of buildings and energy-efficiency improvement in industry and tourism should a full priority by the private sector.
iv) The onus should no more be on the CEB to provide 100% of electricity needed by industrial, hotel and commercial promoters. The latter should be required to ensure optimal design and energy use on their facilities, including the

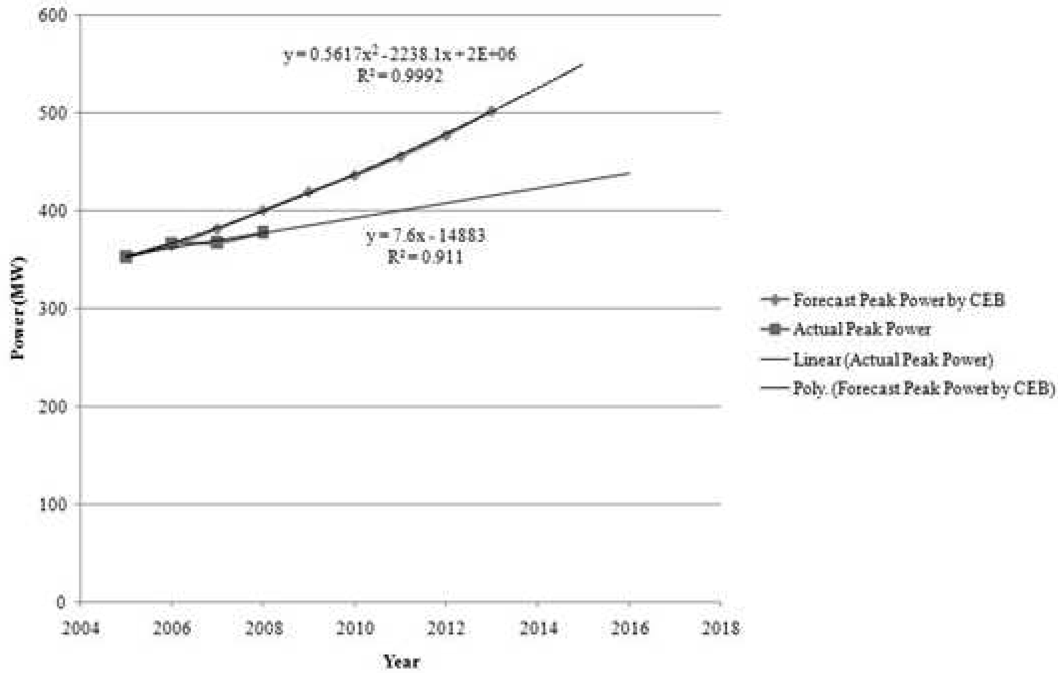

Figure 6. Forecast of peak electricity demand and comparison with actual
Source: CEB (2007b)

implementation of Energy Management programmes and recourse to renewable energy. New cities and similar projects should be subjected to strict environmental standards, including energy use. The proposed Land-Based Oceanic Industry (MLBOPL, 2009; MRC, 2010) is an example of such a new approach where promoters are responsible for sustainable energy input.

v) Pricing policy for energy, including Time-of-Use Tariff for electricity and feed-in tariffs, as well energy taxes should be integrated within a MID Business Framework, together with incentive packages for sustainable energy.

3. New MID scenario

In 2007, the Outline Energy Policy (OEP, 2007c) was published focusing on changing the dependence of the country on oil to one on coal. The Compromise Scenario shown in Table 2 was the one retained by the CEB. The All Sugar Cane Scenario was rejected on the basis that it would have had an estimated extra cost of 5%. The 15 MW coal/bagasse project scheduled for 2008 did not happen. Thus far, no project has been completed. The current intention of the CEB to promote the construction of a 110 MW coal-fired plant and to invest in a 30 MW fuel oil-fired plant implies that the Base Scenario is very much the one on course, albeit with a delay of two, if not three years.

The Compromise Scenario would have also included the closing down of the 20 MW Beau Champ plant in 2009 and its replacement by an equivalent power plant in FUEL in 2009. This did not happen. A 20 MW Waste-to-Energy project and a 25 MW wind farm, concomitant with the Compromise Scenario and expected to start operating in 2009, are also behind schedule. In fact, the former has now been degraded to a 7 MW proposal and is subject to much controversy just like the coal-only power plant.

The concept of Maurice Ile Durable (Mauritius Sustainable Island, MID) started to be formally implemented in 2008. At the heart of the MID

Table 2: Scenarios for power generation
Source: OEP (2007d)

Year Scenario	*Base Scenario*	*Sugar cane Scenario*	*Compromise*
2008	30 MW diesel	42 MW coal/bagasse	15 MW coal/ bagasse
2009		42 MW coal/bagasse	50 MW coal
2010	50 MW coal	42 MW coal/bagasse	50 MW cCoal
2011		42 MW coal/bagasse	15 MW coal/bagasse
2012	50 MW coal		

vision is the need to shift from fossil fuels, including coal, to renewables and to promote Demand Side Management (DSM). The vision is that in 2028, as much as 65% of the energy mix for electricity generation in Mauritius should come from renewables (MID Fund, 2008). This was confirmed by the Prime Minister in December 2009 in Copenhagen with an appeal to help Mauritius achieve its objective (IELS, 2009).

The delays imply that the capacity margin is at an extremely dangerous level of -70 MW currently with respect to the initial planning made in 2007 (OEP, 2007e). Catastrophic black-outs would have happened had it not been for the success of the DSM efforts explained earlier. Moreover, it has been reported that CEB is stretching the use of its resources and this is not without undue risk. Possible accidents due to regular switching on-and-off of generators designed to operate constantly cannot be excluded (Bibi, 2009). Similarly, equipment is being used beyond their normal lifetime.

The Sugar-Cane Scenario offers best safe-guard in the medium-to-long term against negative capacity margins. The argument that it would have cost 5% more than the Compromise Scenario is not a sound one to justify, alone, its rejection. Moreover, the re-engineering of the cane sector is a matter of strategic importance for the country.

Figure 7 illustrates the consequent evolution of the capacity margin in MW, including the benefit related to DSM, for a new MID Scenario that is described in Table 3. The initial planning with respect to the timely retirement of CEB old engines is retained in this scenario. The capacity margin is the difference between the forecasted peak demand and the available capacity, allowing for maintenance, repairs and spinning reserve. The CEB initial forecast for demand is used as benchmark in this case.

The new MID scenario rests on three pillars:

i) Large plants: It replaces the controversial coal-fired power plant by bagasse-coal plants that operate in cogeneration with high efficiency in the context of the re-engineering of the cane industry. The use of other biomasses like cane-top residues will be promoted. Biogas also can be used. It favours the active and urgent implementation of the wind power projects. It assumes the coming into operation of a 30 MW fuel-oil power plant in 2010, as already purchased by the CEB. In the long term, this facility should, however, switch to biofuels.

ii) Small plants: It also envisages the emergence of Small Independent Power Producers (SIPPs) producing electricity either for the grid or for local use (biogas, hydro, photovoltaic and wind power units of less than 50 kW). A number of higher capacity renewable power projects should also start within that scenario (e.g. biogas, micro-cogeneration, trigeneration or hydropower projects of up to 2 MW). Stored or pumped hydropower will also be optimally exploited to reduce peak demand.

iii) DSM: The peak reduction due to DSM should be sustained under the MID Scenario and consolidated to reach a total of at least 30 MW by 2012. This corresponds to an annual growth in demand of 2 to 3 % as compared to the unsustainable 5 % average noted over the past decade.

Table 3: New MID Scenario

2010	30 MW fuel oil at Fort Victoria (confirmed, later switch to biofuel)
2011	50 MW bagasse/coal cogeneration + 20 to 40 MW wind + SIPPs
2012	50 MW Bagasse/Coal Cogeneration + 50 MW wind + SIPPs

Whilst being more sustainable, the new MID scenario also responds to immediate priorities related to energy security, the re-engineering of the cane sector and ensuring availability of electricity. These projects are technically ready to be implemented, some having lingered in the development stage for more than five years. The new scenario paves the way towards reaching the key targets of the MID project. The Compromise scenario, and even more the Base Scenario, will drift the country away from

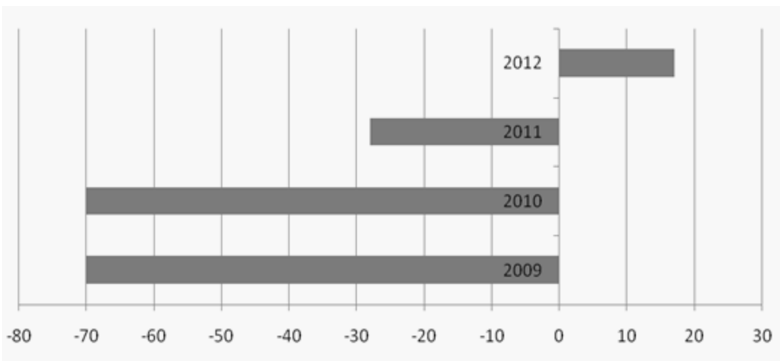

Figure 7. Capacity margin (MW) for New MID Scenario

that vision with the reliance on coal peaking at 54% for electricity generation by 2013 (MPU, 2007f; MREPU, 2009). It is to be recalled that the price of coal has known a rapid increase recently and that its access costs, as well as other hidden costs, are more than 40% of the mine-to-user cost. Above-all in an era of global climate change, turning towards imported coal at the expense of indigenous resources is simply ridiculous.

The main obstacle to the new MID Scenario, however, is of a politico-administrative nature. A new partnership must be defined between the public and private sectors. The agreement reached by the Prime Minister with sugar cane-producers in December 2007 should serve as basis for innovative win-win agreements between the two parties. The Cane Democratization Fund is an initiative in the right direction opening up the ownership of bagasse-coal cogeneration plants to all stakeholders in a spirit of equity (MLP, 2 010).

The controversial and over-delayed projects for a coal-only power plant and a Waste-to-Energy plant are discarded under the New MID Scenario and replaced by a more sustainable alternative.

4. Conclusion

The maximum peak electricity demand will still occur during week-days in summer, but in the morning rather than in the evening. Base and Compromise scenarios for electricity supply have been proposed in the past based on overestimates of actual demand. DSM opens the way to a New MID Scenario favouring energy efficiency and the use of renewables.

As a matter of fact, in spite of all the delays in the installation of additional capacity, Mauritius has not faced any catastrophic black-out yet. This is due to the grossly over-estimated forecasts, successful DSM projects and lower economic growth. The energy-intensive sectors like manufacturing industry and agriculture are also regressing as the expense of the services sector. Another factor that has helped avoid blackouts, or even load- shedding, has been the overstretching of CEB facilities which is never done without risk.

There is the possibility of stabilizing maximum peak demand – in fact, achieving a high plateau spread over several hours in the morning – at around 400 MW by 2012. This will also bring the capacity margin to +17 MW by 2012. Thereafter, there will be an optimal use of available installed capacity, both during peak and off-peak periods, resulting in a growth of between 2 to 3% of electricity demand annually. The corresponding peak demand growth will be even less after 2012, particularly if the morning demand due to ventilation, air-conditioning and refrigeration is addressed properly. The capacity margin will also increase positively.

Such outcomes will require urgent action towards implementing DSM (including institutional and regulatory measures) and introducing a coherent Business Framework to favour the new MID Scenario for both centralized large plants and decentralized small power producers. The survival of the cane industry as well as the opportunity of producing bioethanol from the latter industry are closely related to the implementation of efficient cogeneration plants where the use of bagasse, cane tops and leaves as well as biogas is promoted. Sensitization, education and training should also not be neglected both for the sake of DSM as for the emergence of a green economy.

The need of back-up for renewable energy projects will be best handled through the integration of intermittent sources as well as the combination of scattered decentralized units of diverse nature. Storage of energy and the recourse to forecasting of output from intermittent sources will be extremely useful. Phased-out diesel or fuel-oil equipment as well as disused hydropower facilities can still be used to provide emergency response.

This paper discusses the transition to a sustainable energy future. After 2012, more ambitious projects like photovoltaic parks or geothermal power can be considered in the context of a long-term energy master plan.

To conclude, a holistic approach will have to be adopted putting politics and economy in the service of society and its environment. This is the essence of the MID project.

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Received 24 May 2010, revised 18 January 2011