Blowing away the base-load argument

For electricity planning, ‘base load’ most accurately refers to a subset of electricity demand, or use. It is the portion of demand that is required continuously - 24/7 - or the level below which demand does not ordinarily drop across the system as a whole. A centralised electricity system must be able to meet the entire portfolio of demand (including but not only the baseload demand) at all times. There are different ways to ensure that this is possible. The term “baseload” is applied in a similar way to electricity supply, but supply comes from a combination of different power plants, any one of which could fail at some time, requiring that the system as a whole has some reserve generation capacity to be able to always meet the demand.

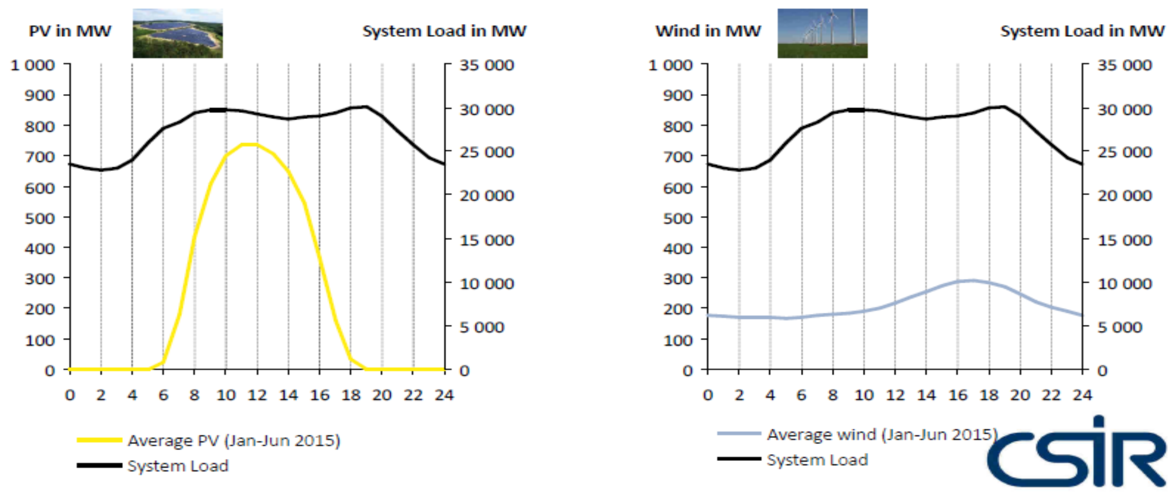
When applied to electricity generation equipment, the term ‘base-load plant’ is used for the technologies and plant designs that are well suited to operating 24/7. These are different to ‘load-following plant’, a term used for technologies and plant designs that are able to quickly ramp power generation – to speed up or slow down - to meet changes in demand. Individual power plants are usually designed to serve a chosen portion of total demand, particularly in a centrally planned context such as the South African. Most of Eskom’s generation is made up of typical ‘base-load plant’, designed to burn low-quality coal in huge boilers continuously, though they must periodically be shut down for maintenance.

The fatal flaw in ‘the base-load argument’, as routinely used to argue for continued reliance on and investment in coal and/or nuclear power plants, is the assertion that because ‘base-load plant’ is well-suited to continuous operation, we must therefore have such power plants to be able to meet base-load demand. There is ample evidence and increasing demonstration of ways to meet base-load demand without big coal or nuclear plants (or having massive amounts of electricity storage capacity), but they are not yet considered in official electricity planning.

Recent research by the Council for Scientific and Industrial Research (CSIR) should put to rest the argument that we need a special kind of plant or fuel to be able to meet base load demand. Based on data from the actual performance of generation from renewable energy in South Africa over the last few years, it shows how intelligent electricity system design and operation offer better ways to meet all electricity demand, including for the energy-intensive industries that use electricity 24/7.

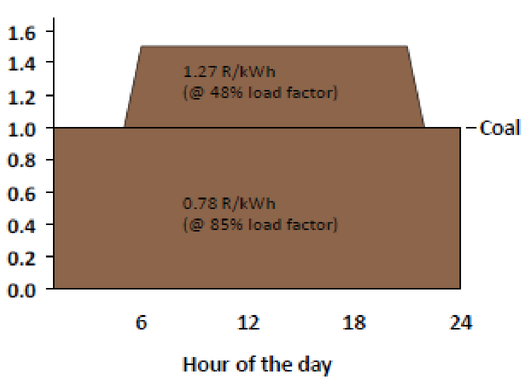
The traditional conception of electricity supply is based on a horizontal organisation of aggregate national electricity demand, distinguishing base load demand from peak demand, which happens over fairly short periods of highest consumption, especially in the early evening; between these is mid-merit demand. Traditionally components of the supply system are developed to generate for the three categories of demand, with South Africa building amongst the largest ‘base-load plants’ in the world. Such plants are effectively designed to convert coal to cash via electricity on as continuous a basis as possible.

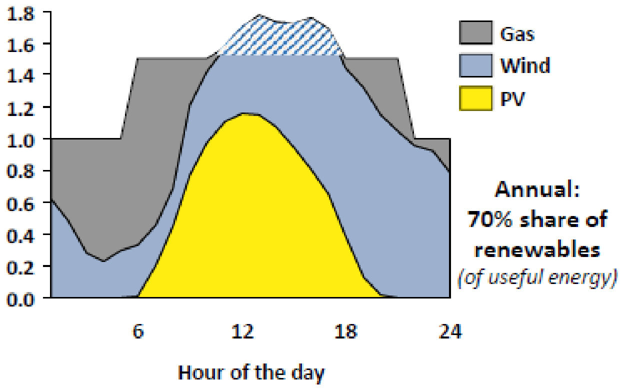
A modern conception of electricity supply is offered by the CSIR in a presentation ‘Opportunities for Renewables in South Africa’ (August 2015). It starts by looking at supply on its own terms, focusing on predictably available solar and wind resources. A study was undertaken (with Eskom and international partners) to determine the portion of regularly available resources that can be relied upon, the Wind and Solar PV Resource Aggregation Study for South Africa (CSIR, 2016) The following indicative daily average supply profiles are drawn from reported generation in SA over the first 6 months of 2015, during which time Wind and PV contributed almost 2% of power supplied to the grid:



The daily average level of power generation is to be read against the left axis, with the timing of generation put in perspective by the total daily load profile, shown in the upper line, to be read against the right axis, i.e. the two lines within the graphs are on very different scales, with solar peaking at about 2.5% of the total midday system load (750 MW out of 30 000) and wind most available in the late afternoon and early evening. This is not the solar and wind resources to be relied upon, which is a more complex calculation, undertaken for the Aggregation Study using a several years of daily weather information.

Based on an holistic understanding of demand and available supply, generation from variable renewable energy resources is treated as the foundation of supply, with any demand that is not met by this supply treated as 'residual load'. The graphic below right is a sketch of this approach, showing indicative solar plus wind generation, on a schematic presentation of the traditional base-load and mid-merit conception of supply capacity, as shown below left. In the graphic the residual load filling in supply around the available renewables is labelled as Gas, but could also be met with storage and other flexible generation options. There is also some surplus supply (the striped area) that could go to some kind of storage or other use:





The purpose of the Aggregation Study was to explore the generation potential of variable renewable energy resources in South Africa, but it also serves to illustrate the viability of this integrated approach to supply and demand. It used national weather data from 2010 – 2012 and modelled how different quantities of solar PV and wind generation capacity could have met different proportions of a theoretical annual supply of 500 TWh of electricity, which is more than double South Africa's current electricity consumption. Since excellent solar resources are very widespread, but available for a shorter time, a key research question was how best to utilise wind and therefore nine different scenarios for the distribution of wind farms was considered.

The following table shows the different contributions, shown in TWh, that would have come from different amount of generating capacity, shown in rounded numbers of GW installed, in brackets. For example bottom right we see that about 104 GW of solar PV plus 75 GW of wind capacity could provide 75% of an annual demand that is double our current demand.

Three solar PV and three wind penetration levels defined

Overview of combination of solar PV and wind scenarios; load scaled to 500 TWh/yr total electricity

Load for all scenarios: 500 TWh/yr

Solar PV energy penetration (one fixed spatial distribution defined) \ Wind energy penetration	**50 TWh/yr** *(~15 GW)*	**100 TWh/yr** *(~30 GW)*	**250 TWh/yr** *(~75 GW)*
40 TWh/yr *(~21 GWp)*	• VRE Share: 18% • 9 Wind distribution scenarios	• VRE Share: 28% • 9 Wind distribution scenarios	• VRE Share: 58% • 9 Wind distribution scenarios
80 TWh/yr *(~42 GWp)*	• VRE Share: 26% • 9 Wind distribution scenarios	• VRE Share: 36% • 9 Wind distribution scenarios	• VRE Share: 65% • 9 Wind distribution scenarios
200 TWh/yr *(~104 GWp)*	• VRE Share: 44% • 9 Wind distribution scenarios	• VRE Share: 52% • 9 Wind distribution scenarios	• VRE Share: 75% • 9 Wind distribution scenarios

Note: VRE = variable renewable energy, which is solar PV and wind (the only two variable power sources; dispatched by the weather and npt be the owner / system operator)
VRE share is calculated on the basis of „useful VRE per total electricity demand", i.e. curtailed VRE is not considered in these numbers

Further work will still be needed to determine just how much flexible generation capacity will be needed to provide the remaining 25% residual load, with technologies including concentrating solar thermal power with storage and biogas-fired peaking plant, but it is now completely clear that we do not need "base-load plant" or any fossil fuels or nuclear power for a plentiful and reliable supply of electricity.