Rapid developments in medical technology, the paradigm shift to patient and family-centred care, and the inability of ageing hospitals to accommodate the latest models of care, have all contributed to the current worldwide boom in hospital redevelopment, writes Keith Davis.

The evolving ‘new breed’ of hospital is welcoming, less threatening to patients, integrates sympathetically with the local community, and embraces evidence-based design principles. These new hospitals are now more integrated into their local communities than ever before, and with this attitudinal change comes new pressures for our ‘new-look’ hospitals to become exemplary neighbours.

Taking a lead in implementing sustainability initiatives is fundamental to this new image, and correlates strongly with the principles of evidence-based design that focuses on stakeholder wellbeing.

By nature of their function, hospitals are major users of power and water, not to mention historically being major environmental polluters. Melbourne’s new Royal Children’s Hospital (RCH) is not only regarded as a world-class facility by virtue of its design and cutting edge medical technology, but it also incorporates the very latest building services technology and sustainability initiatives.

The new RCH site is located in parkland and directly across the road from Parkville residences, which provided even greater incentives to ensure that the new complex qualified as being as “green” a neighbour as possible.

Significant ESD targets were defined at the outset for the new RCH by the Victorian government in relation to the reduction of energy, carbon dioxide and potable water use. This strategy has ensured that this new healthcare facility significantly raises the sustainability bar for other planned major healthcare facilities. The two key RCH initiatives implemented include a blackwater treatment plant (a hospital first) and secondly trigeneration, with both systems playing a significant role in meeting and exceeding ESD targets.

The trigeneration plant and technology engineered by Norman Disney & Young (NDY) is undoubtedly one of the cornerstone ESD initiatives implemented for the new RCH. Apart from the carbon reduction benefits provided, it will also produce electricity and heat energy with a system efficiency of around 78 per cent.

This higher efficiency level is far in excess of the 35 to 40 per cent system efficiency associated with grid power. The poor efficiency of grid power is largely due to the traditional coal-fired generation plant currently employed as well as transmission and distribution losses which account for around eight per cent.

RCH has a heat-led trigeneration system comprising of two 1160kW gas reciprocating engines and two 1267 kWt 2-stage absorption chillers. The system generates 25 per cent of the RCH base building electrical demand, plus a contribution to chilled water and heating hot water for air conditioning, and a heating contribution to domestic hot water. Carbon reduction from the trigeneration system is around 37 per cent, with a further 10 per cent reduction in carbon emissions from the use of a renewable technology biomass boiler (burning compressed timber pellets from forestry waste) and solar pre-heating of domestic hot water serving the inpatient unit. The two trigeneration engines also contribute to the 100 per cent overall standby capacity which operates in the event of a grid power failure.

There are significant environmental gains from the on-site generated electrical contribution which offsets the need for the equivalent capacity in much less efficient grid power and effectively reduces the electrical demand by 25 per cent. Further benefits accrue from the recovery of otherwise wasted heat for use in space heating and cooling which mean that the equivalent capacity of heating and cooling is saved from needing to be generated via gas fired boilers and electrically powered chillers.
Diagram 1

While trigeneration is not “a replace all” solution, it does mean that the overall capacity of the conventional electric chillers and gas boiler plant can be somewhat reduced in capacity.

So what exactly is trigeneration?
Essentially, trigeneration is a three-way complex central plant system employed to generate electricity, heating and cooling. The system generally comprises multiple units of natural gas-fired engines or gas turbines, the latter being more suited for larger installations. These prime movers are close-coupled to alternators which generate the electrical component. The heat generated from the prime-mover combustion – which ordinarily would be discharged to atmosphere via the exhaust system – is captured and used to generate heating hot water and chilled water for air conditioning (see diagram above).

The RCH chilled water requirements produced in part from the trigeneration waste heat is generated by absorption chiller plant, the operation of which is not dissimilar to that of a gas-fired camping fridge. The cooling cycle involves compression and evaporation phases and a chemical process plus an exchange of heat. Steam or hot water enters the absorption chiller and produces chilled water plus a quantum of waste heat which is then rejected to atmosphere via water-cooled heat rejection plant at roof level. This heat rejection plant requires a significant quantity of potable water for cooling and it is in this context that a major saving in potable water is achieved by using recycled Grade A water from the blackwater treatment plant which ordinarily would be lost to the sewer.

Logically there is little need to run a trigeneration system when the requirement for space heating or cooling is significantly reduced. For this reason it is essential to ensure that the plant is appropriately sized. If a heat-led system is oversized, at low electrical and/or thermal demand the trigeneration will shut down and any benefits of having the system are effectively lost. Parameters used to assess the economic feasibility of a potential trigeneration system address hours of operation, lifecycle assessments and carbon reduction potential.

The new RCH is unique in nature and comprises both a category 1 hospital and large medical research facility in the form of the Murdoch Children’s Research Institute, plus retail and significant undercover parking. This uniqueness complicated benchmarking of the new RCH against past hospital developments. To address this issue, NDY was able to develop individual load and operating profiles for each functional space – such as offices, IPUs, ambulatory care, clinical and laboratories – taken from previous project experience and international benchmarking. These were then applied on a pro-rata area basis to establish the overall building model.

This effectively meant that the load characteristics for the building were developed from scratch and modelled by constructing the predictive load profiles for the building electrical demand, cooling demand and heating demand over a year in order to take account of the seasonal effects. The modelling also took into account the operational diversity across the various departments.

In electrical terms the trigeneration system operates in parallel with the grid. The RCH system is designed to prevent the on-site generated power being fed back into the grid during periods of low site electrical demand. This aspect is strictly monitored by the supply authority because it can potentially compromise the effectiveness of their system switchgear. The fault capacity of the supply authority network is designed to accommodate a potential fault current calculated on the basis of a remote power station and significant lengths of distribution cables.

Connection of trigeneration plant at the consumer end of the supply chain serves to boost supply authority network fault currents. Thus if the supply authority network experiences a network fault, the consumer trigeneration plant will contribute to the level of the fault current and potentially rise above the capacity of the grid protection switchgear with potentially disastrous result.

But what if this restriction can be removed? Options are to either force the consumer to closely manage their fault contribution to disconnect their plant when a system fault occurs, or alternatively for the supply authority to upgrade their distribution network to the extent that they are able to buy back power from the consumer trigeneration plant.

I understand this network fault capacity restriction is being addressed by the supply authorities via progressive upgrade works to their networks.

An accelerating of the supply authority network upgrades combined with an increase in the buy-back tariff to a more commercial rate, would inevitably see a significant growth in the size and coverage of privately owned and managed trigeneration plant. Such growth would in turn significantly reduce consumer dependence on our traditional coal-fired power stations and will produce a significant positive step toward carbon reduction across the nation.

For further information, see www.ndy.com/health.

As director of health services at leading engineering consultancy Norman Disney & Young, Keith Davis is responsible for the strategic direction of NDY’s healthcare group in Australia and New Zealand. Davis brings to NDY extensive hospital and laboratory experience over the past 35 years, as a consultant in South Africa, London and Australia.