Beyond energy – facilities managers and the health and pollution considerations when implementing trigeneration

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The green building revolution has seen the emergence of cogeneration and trigeneration systems as a means of generating energy on site and reducing the environmental impact of a building. At present, there are approximately 50 sites across Australia that have adopted the technology, with varied success. A by-product of trigeneration systems is nitrous oxides (NOx), which have the potential to form nitrogen dioxide (NO_2) in the atmosphere. NO_2 is a toxic compound and can have adverse health effects with both short- and long-term exposure.

What is trigeneration?

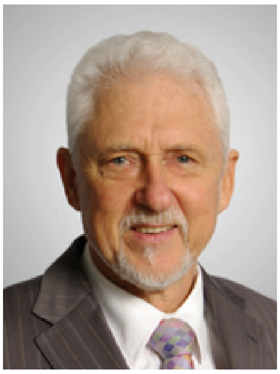
Trigeneration is seen as a highly effective means of increasing energy efficiency by transforming gas to electricity, heating and cooling using a generator system and an adsorption chiller. Energy generation from typical single-cycle centralised power is approximately 25 to 35 per cent efficient. Advances in trigeneration have predicted that implementation leads to an approximate energy efficiency of greater than 80 per cent. Consequently, there are clear advantages in relation to reducing energy and associated costs.

What are NOx and NO_2, and why the concern?

Nitrous oxides (NOx) refer to oxides of nitrogen including nitric oxide (NO) and nitrogen dioxide (NO_2); both of which are produced from the reaction of nitrogen and oxygen during combustion, especially at high temperatures. As such, both compounds are produced during the cogeneration and trigeneration process and are exhausted from the plant via a plume. Levels are typically further exacerbated in areas of high traffic volumes, such as central business districts (CBDs). Both nitric oxide and nitrogen dioxide are greenhouse gases and are involved in ozone layer depletion and acute and chronic health effects in the human population, and are included in carbon tax considerations.

Nitrogen dioxide is particularly toxic to the human population and is known to have several significant respiratory effects, such as emphysema, bronchitis, and cellular damage within the lung, which can reduce the efficiency of breathing. Individuals who have respiratory problems, the elderly, and infants may be more adversely affected. Importantly, the World Health Organization has recognised the issue of nitrogen dioxide levels within the atmosphere and contends that reduced lung function and growth has been linked to nitrogen dioxide concentrations currently being measured in Europe and North America.

The current airborne standard for exposure levels of nitrogen dioxide, as set by the Environmental Protection Authority of Victoria (EPAV) and the National Environment Protection Council of Australia, is 0.12 parts per million (ppm) for the period of an hour, and 0.03ppm for the period of a year.



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Nitrous oxides also have the potential to form a 'bad' form of ozone in the troposphere (ground level; as opposed to ozone in the ozone layer, which is in the stratosphere). This is because oxygen atoms freed from nitrogen dioxide by the action of sunlight attack oxygen molecules to make ozone. Ozone levels have been linked to premature death, asthma, bronchitis, heart attack, and other cardiopulmonary problems.

Importantly, levels of nitrous oxides and ozone within the atmosphere continue to grow. The Federal Department of Environment, Water, Heritage and the Arts states that annual NOx emissions are estimated to be in the range of 82.6 kilotonnes per annum to 117.4 kilotonnes per annum[1]. Furthermore, a New South Wales Report from the Office of Environment and Heritage found that from 1992 to 2008, NOx emissions from industry in Sydney had risen by 51 per cent and were predicted to rise a further 13 per

1 NSW DEPARTMENT OF ENVIRONMENT, CLIMATE CHANGE AND WATER (2010). CLEANER NON-ROAD DIESEL ENGINE PROJECT – IDENTIFICATION AND RECOMMENDATION OF MEASURES TO SUPPORT THE UPTAKE OF CLEANER NON-ROAD DIESEL ENGINES IN AUSTRALIA

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cent by 2016, without even considering any shifts in the location of electricity generation (such as trigeneration). The report contended that this would 'exacerbate the challenge of reducing ozone levels'[2].

A case study from a Green Star rated building

As technical scientific and risk management consultants, CETEC recently undertook an assessment to model and physically test the NOx and NO_2 levels resulting from the trigeneration system and other emission sources levels at a highly credentialled building in Melbourne. Emission levels were modelled and measured at various wind speeds and directions, including at and within the air intakes to the building.

In addition to the trigeneration system, the building had several other potential sources of airborne contaminants; namely those resulting from engine, kitchen, backup diesel generation system, fluid coolers and laboratory exhausts. Each of these sources was modelled physically in a wind tunnel for dispersion under all wind directions and velocities towards the major planned air intakes. A number of critical locations were modelled for NOx, as well as several heights of the trigeneration stack and high and low trigeneration temperatures. The modelled data was provided to CETEC for further analysis, risk assessment, and validation. This modelled data showed elevated NOx and NO_2 levels, and confirmed that there was a potential problem under certain atmospheric conditions.

Following modelling and the completion of construction, validation took place at the air intakes using air sampling techniques. The sampling indicated that levels of NOx and NO_2 were elevated at critical locations of the building. Under a certain wind condition, one result indicated a level four times the exposure limit proposed (corrected for an occupant specific safety factor) even when only one stack of the trigeneration was operating at a low capacity, and other emission sources were not operational or present. Independent advice suggested that the conversion of NOx resulting from the system to NO_2 is approximately 40 per cent; however, on-site monitoring and assessment found that the conversion was as high as 80 to 90 per cent. This makes any modelled data even more significant.

As a result of the modelled and verified results of NOx and NO_2 levels at the building, the recommendation was made to install gaseous adsorption filtration at all air intakes.

2 NSW OFFICE OF ENVIRONMENT AND HERITAGE (2011). INTERIM OEH NITROGEN OXIDE POLICY FOR COGENERATION IN SYDNEY AND THE ILLAWARRA

Risk assessing the building and the occupants

There are a number of factors that contribute to nitrogen dioxide levels being a risk. They include the source, the duration of the source, and the characteristics of the occupants. For example, several immuno-compromised individuals may need to be considered outside of the accepted EPAV standard following a risk assessment.

For a continuous source such as the trigeneration system, with the cumulative effect of other sources, the likelihood that the worst wind direction could persist for several hours several times per year, and the fact that the building could house sensitive people, it was imperative that a further risk assessment was undertaken in relation to this environmental limit. It was proposed that a safety factor be applied to the limit, leading to a stricter exposure level for NO_2. This limit was supported by the client and the constructor.

Other considerations

Some other critical considerations for facilities managers in relation to trigeneration include:

- the capital cost of the system
- the connection process and why the facilities manager can't feed back into the grid
- start-up issues affecting indoor environment quality, including VOCs and particulate matter
- noise; for example, following their green building's first birthday, Olivia Tattam from EPAV stated that '...when the plant was in full operation it exceeded maximum noise levels for neighbouring buildings. This was then rectified quickly with the installation of an extra silencer, taking it to one year from installation before it was operating successfully.'[3]
- increasing fuel source on site leading to increased fire risk and VOCs
- the impact of emissions on neighbouring buildings and airborne pollution issues
- breakdown/reliance issues
- maintenance of gaseous filtration and/or emission scrubbers
- the volatility of gas market prices, because although trigeneration reduces the reliance on electricity from power station sources, it is still utilising a resource that can be volatile in terms of price, supply, and demand
- chemical additives to the exhaust to limit NOx.

Possible solutions for emissions issues resulting from trigeneration

There are a number of technologies that could provide solutions, including Strobic fans, emission scrubbers and gaseous filtration. All of these are additional costs, both in terms of capital costs and maintenance costs. Additionally, some do not solve the problem adequately. For example, although gaseous filtration for HVAC will restrict the NOx from coming into the building, it will not solve the problem of emissions polluting neighbouring buildings (which are unlikely to have gaseous filtration on their air-conditioning system). Gaseous filtration also requires more space in plant rooms – an issue for retrofitting.

Additionally, the case study presented in this article considered the use of Strobic fans and increasing the stack heights. In both cases,

3 HTTP://WWW.CARBONINNOVATORS.NET.AU/NEWS/MATTERS/NEWSLETTER-13-DECEMBER-2010

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the effect was not sufficient to reduce the risk to the occupants of the building, and neither can be considered as solutions to reducing the overall environmental impact of increasing NOx and NO_2 in the atmosphere.

Chemical additives such as urea may themselves convert to other pollutants that would require further analysis.

What's next?

Trigeneration continues to gain popularity, especially with the increase in the availability of funding from environmental upgrade agreements; however, the environmental and health impacts of trigeneration are not yet properly understood or addressed. The property and construction industry needs to be aware that a market shift to widespread trigeneration implementation is essentially relocating emission sources from rural areas back into built-up city areas, which, in turn, will change the amount and distribution of harmful greenhouse gases.

Consequently, while the implementation of a trigeneration system is likely to be a significant factor in reducing the energy costs of a building, it needs to be implemented with an appropriate health risk assessment approach. The design of the system and the subsequent behaviour of the emissions need to be closely scrutinised, modelled, and verified using validation measurement and scientific data assessment. A risk assessment, specifically in relation to the occupants and the public, must be a paramount consideration. This should be done in consultation with various stakeholders, including the relevant regulatory bodies.

The impacts may be seen by occupants, facilities managers and policymakers for many years over the life of the building, with significant and costly outcomes; many of which could far outweigh the savings from energy. A risk assessment approach will ensure that these potential problems are addressed and potentially mitigated. FP

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