1 Potential areas of application of Atlant

ART's best estimate is of the cost of additional water into storages given a rainfall enhancement of five per cent (considerably lower than estimated in trials to date) is below $30/ML or $.03/KL. The following addresses the benefits of such additional water in various areas of water shortage.

1.1 Broad acre industries

The broad acre agriculture sector, which produced $23 billion in 2008-9, is the most rainfall dependent sector in Australia (ABS 2010). Changes in the level and timing of precipitation have a significant effect on agricultural productivity. The direct effects on farm income flow on to the rural and state national economies. Forecast reductions in rainfall associated with climate change are of major concern because farm income is greatly affected by seasonal rainfall. The wheat industry, which is worth $6 billion, is one of the most at risk. It has been estimated that future expenditure on climate adaptation in the wheat industry could be $100 to $500 million per year (Kingwell 2006). The direct effects on farm income flow on to the rural and state national economies.

Also at risk from climate change is the productivity of the forestry industry, which produced logs worth $1.9 billion in 2007-8. Tree mortality associated with reduced rainfall is the main concern and can be as large as 40 per cent ($400/Ha per annum) (Taylor 2009), and the only alternative adaptation option for established plantations is to thin the plantation to reduce mortality of remaining trees (Stokes and Howden 2008).

The Atlant technology can offer a low-cost alternative to climate change adaptation, and the benefits of the additional rainfall produced, once demonstrated, are likely to make adoption of the technology a commercially viable strategy for broad acre farmers and to foresters. We clearly have an advantage in addressing water shortages where the coastal alternative solutions of desalination and recycling are not feasible.

We have presented various proposals to the Government of Western Australia, which is keen to proceed with a funded trial over the northern wheatbelt region, should the Federal Government be involved.

We are preparing a comprehensive prospectus for all rural water users of the opportunities for Atlant applications. This will be aimed at irrigation, pasture, crop and forest growth, environmental flows and country centre urban water supplies. We also have proposal to cover the entire Murray Darling Basin, to service pastoral, broadacre, irrigation and environmental needs in the context of the shortages addressed by the Murray Darling Basin Plan.

1.2 Irrigation

Irrigated agriculture is by far the largest user of water resources in Australia. In 2005-6 the agriculture sector used 11,689 GL of water for irrigation and generated a value of agricultural production of $10.5 billion. Irrigation in the Murray Darling Basin represented 66 per cent of total irrigation consumption and produced $4.5 billion. The future availability of water for irrigation is under threat both from reductions to irrigation water entitlements associated with increasing environmental flows and from climate change.

In the Murray Darling Basin, new diversion limits are being developed under the Basin Plan, and it is anticipated that the volume of irrigation entitlements will be around 30 per cent lower than 2008 levels. Climate change is expected to reduce yields on the remaining entitlements. There is limited scope for productivity improvements through adoption of on-farm water savings technology because much of the opportunity for water efficiency gains has already been taken up in the past two decades since the introduction of widespread water markets, and in response to the prolonged drought. Modelling of the water market suggests that the combined effect of the Commonwealth buyback program and climate change will increase the average price on the seasonal water market by 130 per cent in the Murray and 250 per cent in the Goulburn valley (Brennan 2010). As they will be faced with much higher water prices, there will be little difficulty in selling the commercial benefits of Atlant technology to irrigators.

Outside the Murray Darling Basin, water available for irrigated agriculture is also under threat from climate change. This is where the majority of Australia's horticulture production is located, with fruit, grapes, vegetable, nursery and flower industries producing a total value of $4.5 billion outside the Basin, compared to $2.5 billion within the Basin. Those producers that are located in peri-urban areas may find new opportunities for accessing water through the recycling schemes that are being proposed for urban centres. However, those industries located in more remote areas provide a potential market for Atlant technology, both for addressing yield losses associated with climate change as well as losses in entitlement associated with competition from other sectors, including urban and the environment.

A proposal has been presented to the Gwydir Valley Irrigators Association, who have indicated they would consider contributing to a jointly funded government trial.

1.3 Environment

It is widely acknowledged that water dependent ecosystems have suffered from over allocation of water for consumptive uses. In the Murray Darling Basin, the Commonwealth Government originally designated $3.1 billion dollars to reclaim water for the environment. In 2008-9, $771 million was spent on purchasing irrigation entitlements at an average price of $1,500/ML. The price of such entitlements has since risen to more than $2,000/ML. The recently released draft Murray Darling Basin Authority Plan calls for the restoration of a minimum of 3,000GL or three million megalitres. The current attention on such a reallocation of water gives cause for officials, politicians and local farmers to investigate the potential for Atlant to reduce the pressure on the basin's finite supply of water.

Environmental water concerns extend beyond the Murray Darling Basin, to coastal river systems and to lake systems. In southwest WA, an acclaimed biodiversity hotspot region, climate change has been shown to have a devastating impact on the health of water dependent ecosystems.

Atlant technology can provide a number of benefits to the environment, unmatched by non-rain enhancement water supply technologies. In regions where environmental water is held in dams, rain enhancement can increase dam yields and thus provide more water for environmental releases. But rain enhancement is also of direct benefit in providing increased soil moisture for native and other vegetations and reducing the effect of climate change on endangered ecosystems and species, beyond any direct commercial driving benefit.

1.4 Metropolitan water supplies

The recent drought, along with dire predictions of future urban catchment yields, has had dramatic consequences in the urban water sector. Dam levels in all major cities reached critically low levels and resulted in the imposition of stringent water restrictions. It has been estimated that these restrictions imposed a cost of at least $150 per household per year (Grafton and Ward 2007, Brennan et al. 2007, Hensher et al. 2006), which implies a total annual cost of $800m at the national level. Water restrictions and other demand management measures were the only option for managing scarce water supplies in the short term, given the lead time to developing alternative water sources. Now, all major capital cities have invested in desalination, with a total capacity of 467GL across the five major metropolitan regions, at an investment cost of $8.4 billion (Table 1). At the national level, the augmentation provided by desalination represents 20 per cent of the expected yield of conventional supplies, with considerable variation between cities.

Table 1 Recent desalination investments in major capital cities, GL capacity compared to conventional yields, and capital cost.

	Conventional[1]	Desalination	Desal %	Cost $b
Perth	235	95	29%	1.3
South East Qld	468	45	9%	1.2
Sydney	583	77	12%	1
Melbourne	387	150	28%	3.1
Adelaide	200[2]	100	33%	1.8
Total	1873	467	20%	8.4

1. Estimated future yields from conventional surface and groundwater sources adopted in planning processes, accounts for expected climate change losses. 2. Desalination plans for Adelaide include both augmentation and substitution away from existing reliance on Murray.

Desalination has the benefit of providing a rainfall independent water source, but at very high cost in terms of capital and operating expenditure and environmental impact. Desalination does not drought-proof a city, as most water comes from conventional rain dependent sources. In Sydney, desalination only represents nine per cent of total sources, implying that most of the city's urban water supply will remain reliant on the weather. At the national level, 80 per cent of the urban water yield is from conventional sources that depend on probabilistic rainfall. The Atlant technology may be shown to significantly enhance this probability distribution, which will have benefits both in the short term and in the longer term.

In the short term, adoption of Atlant technology in urban water catchments could mean that there will be reduced reliance on emergency solutions that have included urban water restrictions and groundwater mining. Urban water restrictions impose a high cost in terms of reduced amenity in home gardens and in public open space, as well as the cost of restoring gardens and trees lost during outdoor water bans. In Perth, water restrictions were less severe because the water utility was given emergency rights to mine the Gnangara Mound. The extent to which this mining contributed to the present degraded state of the Mound's water dependent ecosystems is controversial.

By improving yields on existing urban water dams, Atlant technology may allow a reduction in reliance on the presently installed desalination technology, which can offer some cost savings in the medium term. The total annual cost of running the 467 GL of installed desalination capacity will be around $500m, and will require 1600GWh of electricity. The improved yield on surface water dams will provide an operating cost saving of around 80 cents per KL and will reduce electricity consumption by around 3.5KWh per KL. These cost savings would result in lower prices to consumers.

In the longer term, a higher expected yield on conventional sources would defer the need to invest in additional supply augmentation, such as desalination, as population continues to expand. A cost comparison, shown below in Table 2, shows the Atlant technology being considerably cheaper than other water technologies.

We have presented a proposal to augment the Perth metropolitan catchments, but the WA Government, as noted, has been keener to begin with an agricultural-focused trial. Other state governments have to date been focused on desalination as the immediate solution to their supply problems.

Table 2: Cost comparison of alternative water technologies (based on Perth).

Technology	Cost
New Dams	$4.11/KL
Desalination	$2.69/KL
Recycling	$2.12/KL
Atlant	<$0.10/KL

1.5 Mining and power generation

The mining sector used 413GL of water in 2004-5 and the power generation sector used 271GL. The future availability of water for these sectors will be constrained by environmental allocations associated with climate change. The Atlant technology could enable these sectors to increase yield on existing entitlements at lower cost. We currently have a proposal with the Gladstone Area Water Board presenting Atlant as an alternative to the proposed 30GL pipeline from the Fitzroy River to the Awoonga Reservoir.

1.6 Developing world aid applications

Many parts of the developing world, particularly sub-Saharan Africa and the Indian subcontinent, have severe water shortages problems, and the availability of water for irrigation is expected to decline over time as a result of competition from other sectors driven by population and economic growth. Climate change is expected to reduce the productivity of rain-fed food crops in these regions. These factors will combine to exacerbate food shortages.

The World Food Program spent $4.5 billion in 2009 in providing food aid in developing countries. The total amount of spending on development aid from OECD countries in 2009 was $137 billion. Atlant operations are potentially a powerful means for the developed world to assist the developing world - it may be one of the most effective options of improving agricultural production in rain-fed environments and thus alleviating world hunger.

2 Technology overview

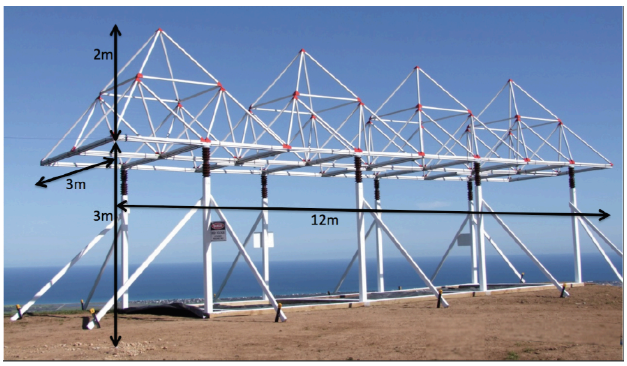
Current literature in the field of cloud and aerosol microphysics suggests that ions can influence the formation of clouds and raindrops at multiple stages throughout the process (e.g. Harrison and Carslaw, 2003 for an overview; Harrison 2000, Carslaw et al. 2002, Khain et al. 2004). In particular, there is evidence consistent with ions enhancing the coalescence efficiency of charged cloud droplets compared to the neutral case. Though electrical effects on cloud microphysics are not fully understood (see Chapter 10 of McGorman and Rust, 1998 and Chapter 18 of Pruppacher and Klett, 1997 for an overview), enhancement of the coalescence process may play an important role in explaining any effect on raindrop formation and consequent rainfall enhancement attributable to the Atlant technology.

However research attempting to link the micro-level effects of ions on the formation of raindrops and the macro-level application of ion generation to enhance rain has been relatively limited. Yet, early experiments into the electrification of clouds, including the widespread releases of ions into the air to test the effect of priming clouds with negative space charges, speculated that electrical charges in clouds could aid in the initiation of rainfall (Vonnegut and Moore, 1959; Moore and Vonnegut, 1960). It was also shown that the electrical conditions in clouds could be modified with the release of ions of either polarity, into the sub-cloud air using a high-voltage power supply that generates corona discharges from an extensive array of small diameter wires elevated above the ground and exposed to local winds and updrafts (Vonnegut et al. 1961, 1962a, 1962b). Recent field experiments have postulated that a DC-corona antennae can be used for the purpose of precipitation enhancement and also as a means of aerosol deposition (Kauffman and Ruiz-Columbié, 2005; 2009). Most recently Beare et al. (2010) reported positive results from a trial of the Atlant rainfall enhancement technology in South Australia in 2008.

2.1 Description of Atlant

Although these previous investigations were not conclusive, they do provide the basis for a plausible hypothesis for how the Atlant system may function to affect rainfall. This hypothesis was used to de- sign key elements of the statistical analysis. Each Atlant ion-emitting device consists of a high-voltage generator connected to a large network of thin metal wires supported on a framework with a series of pyramids on top. The device's approximate dimensions are 12m x 3m x 5m (Figure 1). It consumes about 500W of power and generates voltages of 70kV.

Figure 1: The Atlant at C2 Site (Willunga, SA)



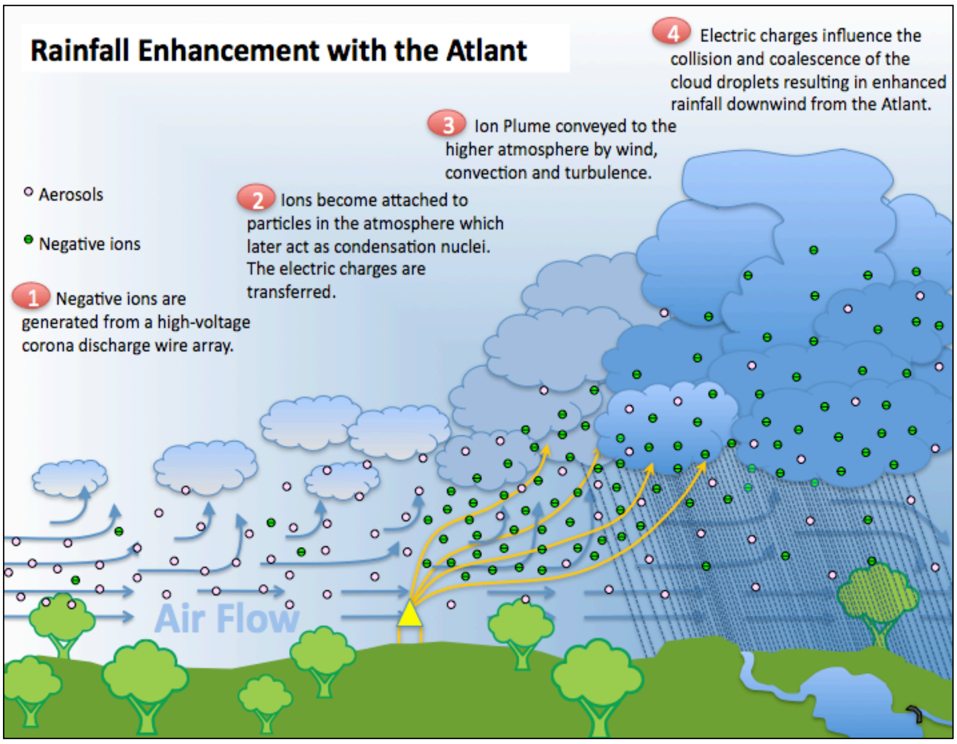
2.2 Atlant model

Assumptions about the operation of the Atlant relate to condensation nuclei and drop coalescence. As scientific literature suggests, the coalescence efficiency between colliding drops of opposite charge is enhanced, as it also is between charged drops and uncharged drops, due to electrostatic attraction.

Many questions remain to be answered about the underlying processes; however, based on current understanding, the working hypothesis is outlined below:

1. Initially, negative ions are generated from a high-voltage corona discharge wire array.
2. The ions will be conveyed to the higher atmosphere by wind, atmospheric convection and turbulence.
3. The ions become attached to particles in the atmosphere (especially soluble particles), which later act as cloud condensation nuclei (CCN).
4. The electric charges on these particles will be transferred to cloud droplets.
5. The increase in cloud droplet charge enhances coalescence, resulting in enhanced rain drop growth rate and ultimately in- creasing rainfall downwind from the Atlant.

Figure 2 Rainfall enhancement process with the Atlant



3 Key personnel

3.1 Evaluation and review

Each trial has been evaluated and/or reviewed by leading independent scientists. The following table sets out the relevant contributing scientists.

Table 3: Evaluation and review team

Field of expertise	Nominee	Affiliation
Statistics	**Dr John Henstridge**	Managing Director Data Analysis Australia Pty Ltd (Adj. Professor of Statistics Uni. of Western Australia)
Statistics	**Prof Ray Chambers**	University of Wollongong, Centre for Statistical and Survey Methodology
Statistics	**Dr. Stephen Beare**	Analytecon Pty Ltd. Former Chief of Research at ABARE

3.2 Scientific Reference Panel (SRP)

The SRP has been established to provide high-level expertise to guide the trials; and to provide independent review of the trial results. The following table sets out current members of the SRP.

Table 4: Scientific Reference Panel

Field of expertise	Nominee	Affiliation
Atmospheric science	**Dr Graeme Pearman**	Independent, former head of Atmospheric Physics at CSIRO
Cloud physics	**Prof Neville Fletcher**	Australian National University, School of Physics and Engineering
Statistics	**Prof Ian Gordon**	Uni. of Melbourne, Director of the Statistical Consulting Centre
Natural resource management	**Prof Wayne Myer**	Uni. of Adelaide, School of Earth & Environmental Sciences
Statistics	**Prof Alan Welsh**	Australian National University, Mathematical Sciences Institute

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