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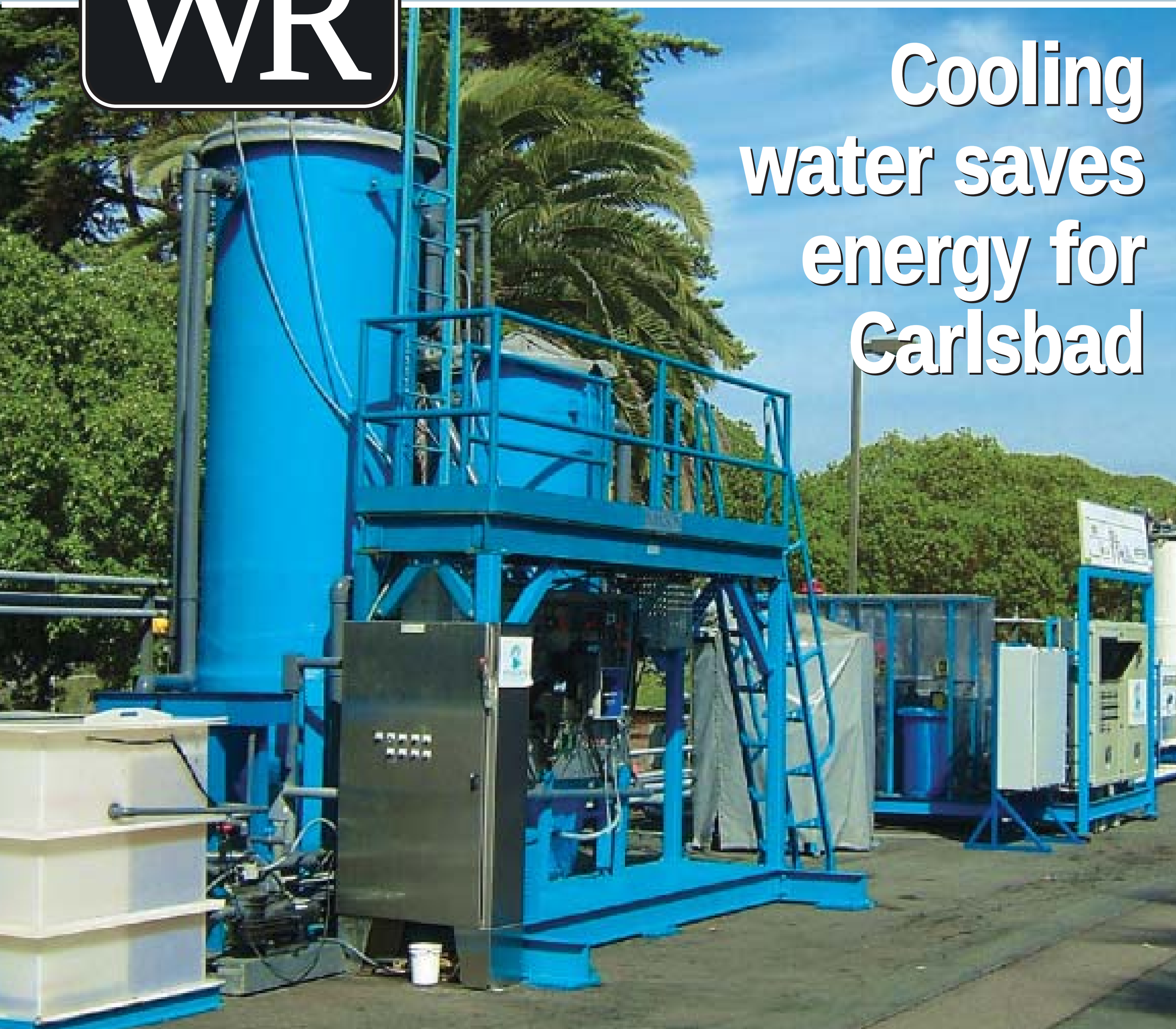
Cooling water saves energy for Carlsbad



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SINGAPORE – Special Feature

PLUS

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Low power bill makes seawater desalination affordable

GG Pique, CEO, Energy Recovery Inc, USA

Editor's note
I mentioned the imminence of this paper a couple of issues ago. Its aim is to look at the real cost of producing desalinated water taking everything into account. Yes, it's promoting one type of device, and no doubt many people will have issues to raise. If they do, I hope they will raise them in the pages of D&WR. Meanwhile, the overall message is one that needs continually repeating to the world: desalination is not always the most expensive option.

Cost of Potable Water in Major Metropolitan Areas Around the World. Source: Global Water Intelligence. Sept. 2004

Cayman	$6.83
Curacao	$5.26
US VI	$3.94
Gran Canary	$3.50
Berlin	$1.97
Frankfurt	$1.90
Amsterdam	$1.79
Birmingham	$1.54
London	$1.49
Vienna	$1.43
Paris	$1.31
San Diego	$1.37
Orange County	$1.22
Naples	$1.20
Perth	$1.05
Sydney	$1.01
Tokyo	$0.98
Singapore	$0.90
Los Angeles	$0.87
Tel Aviv	$0.85
San Francisco	$0.79
Barcelona	$0.71

Table 1— Consumers paying a lot for "potable" water (US $/m^3)

Many coastal communities worldwide—including California, where the author lives and works, lack sufficient water resources to sustain current growth trends. This dilemma is caused by a demographic explosion concentrated along coastal areas worldwide and combined with cyclical variation in rainfall.

As a result of the increasingly scarce availability of drinking water, the cost of water to major urban centers around the world has been increasing faster than inflation over the last 20 years, reaching the following recently published levels:

Even worse, the water available at these increasing price levels is usually of very poor quality. This "potable" water is usually filtered river or lake water, often tainted with high levels of fertilizers, pesticides, and other organic contaminants. This has led to a boom in demand for bottled water and home water purification equipment.

Due to these real and perceived degradations in quality, any detailed analysis of the real cost to the consumer of this "potable" water should take into consideration bottle water substitution and ubiquitous point-of-use final treatment. Think about it: does the ice machine in your refrigerator have a cartridge filter? How much do you pay every time you replace it—what is your real cost of water per gallon?

However, if we were to ask Arnold, our friendly high government official responsible for leading us through this worsening crunch, about seawater desalination as a solution to the increasing price escalation of water, chances are his response will lead with these two mantras:

1- Takes too much energy—energy is over half of the operating cost of desalination.

2- High energy consumption and complicated process makes desalinated water too expensive.

Arnold, our government official may even be armed with one or more dusty studies, backing his verdict with numbers such as the following (see graph below):

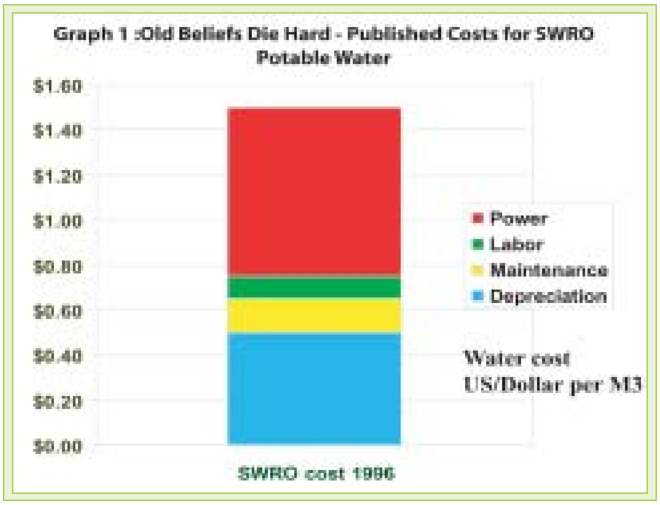


Figure 1: Old Beliefs Die Hard - Published Costs for SWRO

The amazing fact is that our friend Arnold is absolutely correct, based on the best technology available 8 or 10 years ago. And in fact, many World Bank opinions and decisions are still made based on such data. However, all of these officials are wrong based on what is being consistently achieved in many large and small desalination plants worldwide. Wrong not by a little bit, but by a factor of more than two.

As we have analyzed in published articles before1, there are many factors influencing the sharp drop in desalination. To understand the real cost of desalinated water, let us examine some of the large 20-year desalination contracts awarded to "BOOT" investor/operators as part as the ongoing privatization boom worldwide (Table 2).

Hidden Subsidies

As you can see from the comments voiced by various people close to these projects, not all of these plants were bankable (or built, or profitable) at these low contracted water rates. In order to make some of these plants bankable, some of these projects were subsidized by soft pension-fund funding or below-world market energy rates. For this reason, we need to dig a bit deeper to get at the real cost of desalinated water. Let us do some numbers (Table 3).

In a competitive industry such as water, such hard numbers are difficult to come by. However, we are grateful to the award-winning poster presentation by John Kiernan of Ionics to shed some light on a typical BOOT contract rate. In this case John published and discussed with us some very specific numbers for the Trinidad project.

This is fortunate because the author of this work used to work first for Ionics and then for their major competitor, Veolia, putting together large desalination projects, this kind of information is usually covered by confidentiality agreements. The public disclosure of such information allows us to share these numbers with you.

As you can see from these numbers, one thing jumps at you—the low power costs. In an era of $65+ per barrel of oil, we do not believe that that kind of power cost represents what you and I will get from our friendly local utility or real costs if we decide to invest in some diesel generator sets and make our own power by purchasing unsubsidized diesel in the world market.

So in order to get a bit closer to the cost of desalination we need to put some real power costs into the Ionics Trinidad model. Let us see what happens when we do that (Table 4):

Project	Rate/m³	Comment
Hyflux Singapore 140,000 m³/day	$0.46	(Political? Power included?)
Israel Ashkelon Phase I 160,000 m³/day	$0.52	(Pension Fund subsidy)
Israel Ashkelon Phase II 160,000 m³/day	$0.49	(Pension Fund subsidy)
Ionics Trinidad 120,000 m³/day	$0.72	(Low power cost, high risk)
Ionics Hamma Algeria 200,000 m³/day	$0.80	(High finance risk)
Various Israeli Projects	$0.60	(Political risk-not Bankable)

Table 2- Recent History of SWRO - BOOT Contract Rates

Power cost $/m³	Power Cons. kWH/m³	Total Cost US cent/m³
Power @$/kWh 0.02	3.805	7.61
Membranes		3.95
Parts Replacement		6.7
Chemical Consumable		4.8
Op Margin		8.5
Labor, G&A		4.6
Office, Local		1.3
Capital recovery		34.55
Total US cents /m³		**72.01**

Table 3. Case I - Ionics Trinidad
Source: John Kiernan, Ionics Poster Presentation AMTA Tampa 2002.
Actual Capex US $120 million

Power cost $/m³	Power Cons. kWH/m³	Total Cost US cent/m³
Power @$/kWh 0.06	3.805	22.83
Membranes		3.95
Parts Replacement		6.7
Chemical Consumable		4.8
Op Margin		8.5
Labor, G&A		4.6
Office, Local		1.3
Capital recovery		34.55
Total US cents /m³		**87.23**

Table 4. Case II - Ionics Trinidad modified for "real world" power cost
Derived from Ionics Poster Presentation AMTA Tampa 2002.
Actual Capex $120 million US

Wait a minute. Maybe Arnold was right. Look what happened! Our price of water is close to $0.90 per cubic meter. And the desalination energy consumption is over half of the operating costs!

Let us look more closely at the energy consumption of the Trinidad plant. At the time it was designed in the late 1990s, the Trinidad plant used the most advanced, most proven technology available at the time: Super efficient two-stage HP pumps, which can achieve close to 89.5% efficiency, combined with large Calder Pelton wheels, which can also achieve efficiencies close to 89.5%. We will take you through the detailed calculations later, but the main thing to understand here is that the combined net-transfer energy-recovery efficiency of these advanced turbine devices used by Ionics in Trinidad is obtained by multiplying the individual efficiency of the devices:

$$0.895 \times 0.895 = 80.1\%.$$

The fact is that no matter how well we design them—using the CNC machines used by the US Navy to craft nuclear submarine propellers, etc, when we used turbine devices we are going to lose from 19% to 30% of our energy down the ocean. For the large desalination plant in case II above, the energy wasted by turbine energy-recovery devices in a 20-year BOOT deal represents $15 to $30 million in operating costs. So there has to be a better way.

There is—and it is called isobaric chamber devices. Beginning in the 1990s, a new generation of SWRO energy-recovery devices became commercial, which is drastically changing the economics of desalination. This new type of device uses direct energy transfer of the brine energy directly onto the incoming seawater. Because of this direct energy transfer, energy recovery efficiencies of 95 to 96% are commonly achieved.

Even better, this high efficiency performance is maintained even as the operator adjusts the membrane water recovery rate over a fairly wide range to accommodate changes in SWRO membrane performance due to aging, fouling, seasonal temperature variations, salinity increase in beach wells, etc. Over the last ten years, hundreds of small, medium and large desalination plants worldwide have installed these isobaric chamber devices to lower their desalting energy costs.

In some of these plants where isobaric technology is applied optimally, plant operators are enjoying specific energy consumption for the process in the range of 1.8 to 2.2 kWh per cubic meter of desalinated water. If you include all of the other energy costs in the plant including lights, intake SW pumping, and pretreatment, a good, realistic power consumption target would be in the order of 2.4 kWh per cubic meter.

In addition, the Capital Recovery charges published by Mr. Kiernan for the Trinidad project reflect unusually high political and financing risk. These may be lower for more bankable regions—although these may also be partially offset by recent price increases in membranes and stainless steel.

Let us look at what our water costs look like if we take the Trinidad model and we apply both “real world” energy pricing and isobaric technology—as well as capital recovery rates consistent with a low risk situation (Table 5 above).

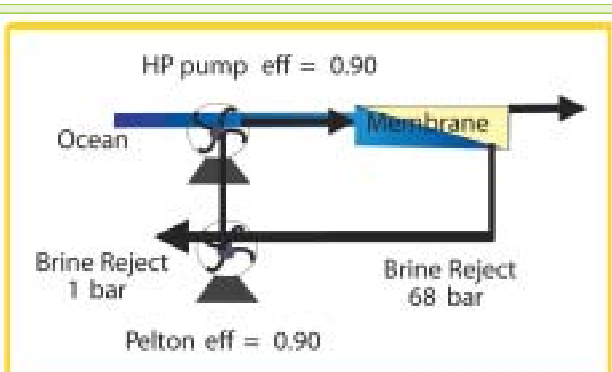
If you analyze the difference in power costs between Case II (Table 4) and Case III (Table 5), you can confirm the following energy savings when plants are designed using energy-efficient pressure cycles and isobaric technology compared with the way plants were being designed just 5 years ago (see Table 6 on page 55).

As mentioned before, the savings afforded by isobaric technology compared with conventional Pelton and Turbo technology depend on train size, operating

Power Cost $/m³	Power Cons. kWH/m³	Total Cost US cent/m³
Power @$/kWh 0.06	2.40	14.4
Membranes		4.0
Parts Replacement		6.7
Chemical Consumable		4.8
Op Margin		8.5
Labor, G&A		4.6
Office, Local		1.3
Capital recovery		21.00
Total US cents /m³		**65.30**

A version of the above with adjustable debt/equity ratios and financial rates is available as a simple NPV model on ERI’s web site: www.energy-recovery.com.

Table 5. Case III - Ionics Trinidad modified for “real world” power cost Derived from Ionics Poster Presentation AMTA Tampa 2002



Each side of a conventional water wheel suffers an energy loss. The “net transfer efficiency” of a water wheel device is obtained by multiplying the combined efficiency of each side. Thus, if the adverstised efficiency of a Pelton device is 90%, the net energy recovery of the device is obtained by multiplying this efficiency by the efficiency of the pump it is driving.

$$0.90 \times 0.90 = 81\%$$

Figure 2 - Water Wheel Inefficiency Multiplication Effect

pressure cycle, membrane recovery rate and other factors. Typically you would expect to save at least 0.40 kWh/m^3 or close to $1 million per year for a 100,000 m^3/d plant.

As you can see in Table 5, if you have access to capital at reasonable costs, it is possible to make "bottle water quality" potable desalinated water from seawater for less than most of the major cities listed in the early part of this paper are paying for filtered river water. This desalinated water is is already softened and devoid of the organics and pesticides often present in treated river water.

Experience from hundreds of installations in the field suggests that the actual savings from PX technology are bigger than those design numbers, because ERI PX technology allows the operator to change the membrane water-recovery rate to adjust for membrane fouling, seasonal variations in temperature etc, and still enjoy 95-96% efficiency. This is a major advantage over Pelton and Turbo technology, which suffer rapid degradation in efficiency if operated at other than the precise design point.

Plant Capacity	Per diem Savings	Annual Savings	20 year BOOT Contract Savings
100,000 m^3/d (25 MGD)	$ 8,400	>$3,000,000	> $60,000,000
160,000 m^3/d (40 MGD)	$13,400	>$4,800,000	> $96,000,000

Table 6. Savings available compared with 5 years ago

Project Technology	Contractor	Capacity	Energy Recovery
Blue Hills Bahamas	CWCO*	25,000 m^3/d	DWEER
YuHuan Power China	CNC	36,000 m^3/d	ERI PX
Emergency Trailers	GE Ionics	10,000 m^3/d	ERI PX
Mexico	CABO INIMA	20,000 m^3/d	ERI PX
FEWA II UAE	Aqua Engr	29,000 m^3/d	ERI PX
Perth	Suez Degremont	140,000 m^3/d	ERI PX
FEWA III UAE	Aqua Engr.	29,000 m^3/d	ERI PX
HAMMA	E Ionics	200,000 m^3/d	ERI PX
Egypt	IET	25,000 m^3/d	ERI PX

Consolidated Water, Cayman, CWCO, is the exclusive DWEER licensee for the Caribbean. This is a captive market sale for a CWCO BOOT project.

Table 7. Energy recovery technology in recent projects

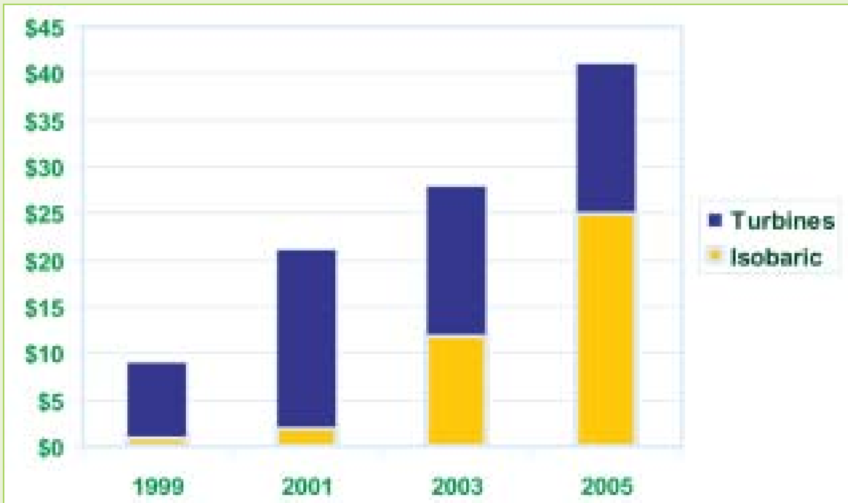


Figure 3 —Isobaric technology taking over market (Energy Recovery capacity contracted or under letter of intent). Figure 3 illustrates how Isobaric technology has gone from less than 5 per cent market share in 2001 to a projected over 60 per cent market share in 2005.

You have to do the numbers for your own plant. We encourage you to visit our website, where we have transparent power models posted which will quickly allow you to do the calculations for your own project conditions. Do the numbers. If the ERI PX does not save you at least 0.40 kWh/m^3, send us your numbers and we will check your design.

As one major client in Israel, who has been buying desalination plants with Pelton wheels for the last 10 years put it after doing the numbers:

"If you can enjoy those energy cost savings, why would you do it any other way."

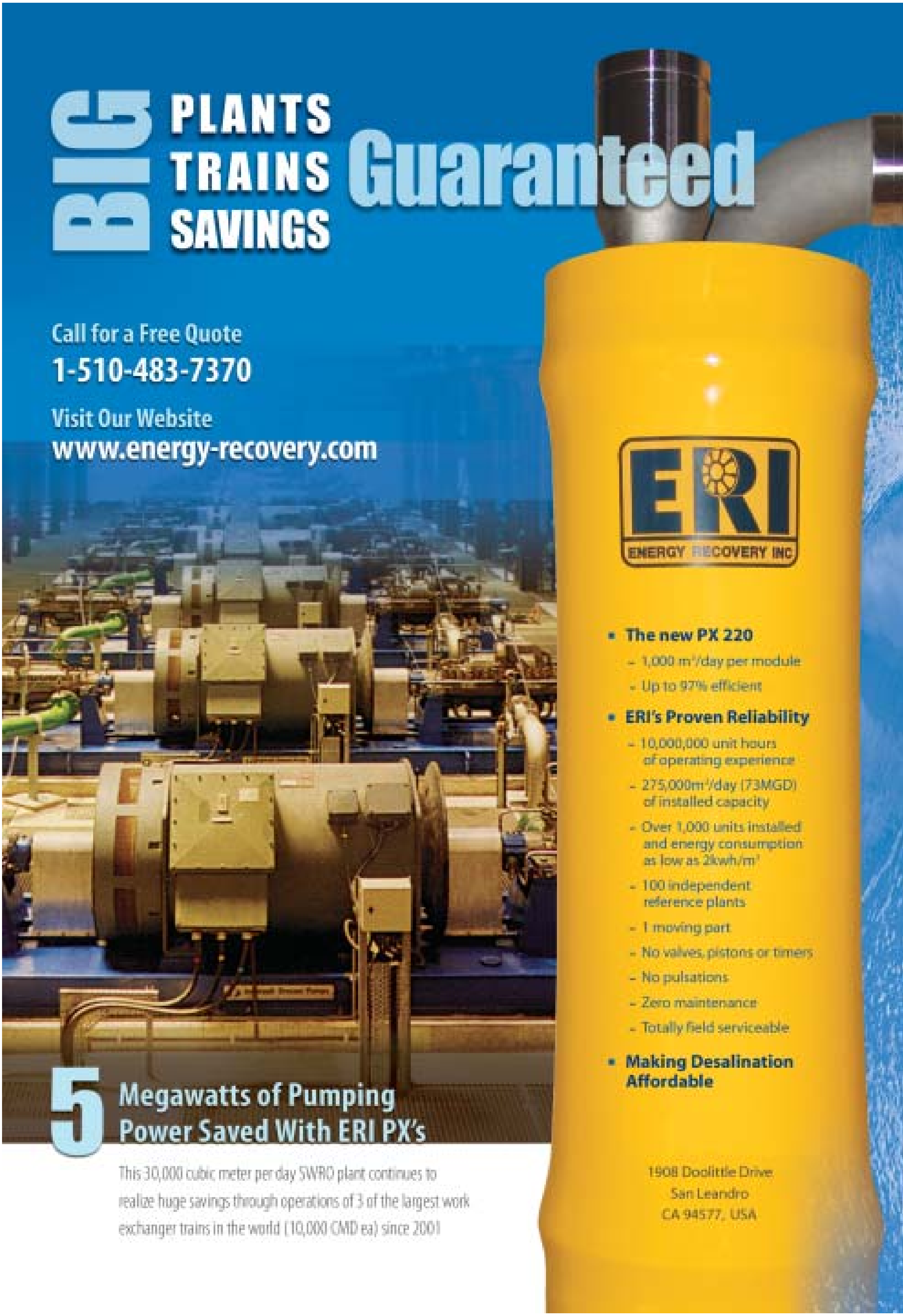
All of the major desalination engineering companies around the world have been performing these power savings calculations. They have also carefully analyzed the life cycle costs for the various SWRO energy recovery options. As a result of this, it is a fact that isobaric technology is rapidly taking over the market.

The projects in Table 7 were contracted over the last 12 months (as of August 2005) include Isobaric technology:

This unusual rapid acceptance (in an otherwise very conservative industry) is due to the fact that this new isobaric technology makes possible the desalination of seawater for less than half the energy compared to the way it was commonly done 5 or 10 years ago. According to Claus Wangnick who tracks this industry, his low-energy, affordable desalination trend has been driving a 20% compounded growth rate.

The energy savings made possible by Isobaric technology is driving this rapid growth. Because of its simplicity and guaranteed highest efficiency, ERI PX technology is leading this affordable desalination boom.

Figure 3 illustrates how Isobaric technology has gone from less than 5 per cent market share in 2001 to a projected over 60 per cent market share in 2005.



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