Another Water Resource for Caribbean Countries: Water-from-Air

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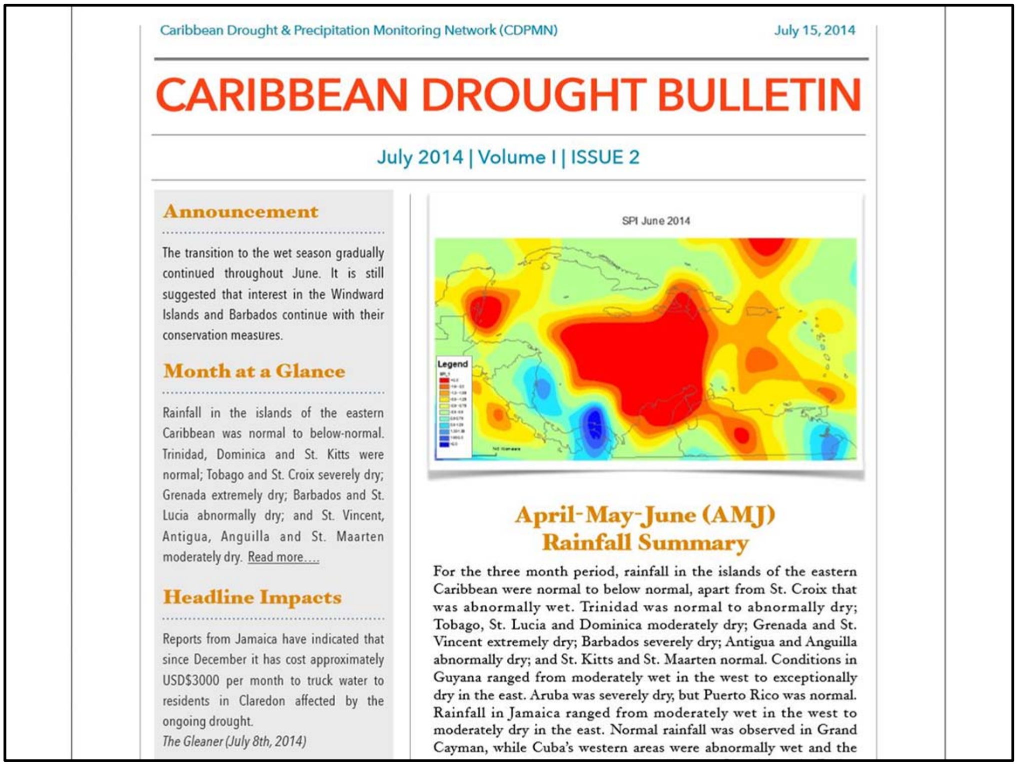
Presentation for a Technical Session at the 23rd Annual Caribbean Water and Wastewater Association (CWWA) Conference, Paradise Island Bahamas (October 2014)

Hi, I'm Roland Wahlgren of Canadian Dew Technologies Inc. Thank you for coming to my presentation about "Another Water Resource for Caribbean Countries: Water-from-Air".

I am here with my business partner, Nigel Carvalho, President of Global Site Solutions Inc., with offices in Vancouver and Trinidad.



Caribbean Drought & Precipitation Monitoring Network (CDPMN) July 15, 2014

CARIBBEAN DROUGHT BULLETIN

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Announcement

The transition to the wet season gradually continued throughout June. It is still suggested that interest in the Windward Islands and Barbados continue with their conservation measures.

Month at a Glance

Rainfall in the islands of the eastern Caribbean was normal to below-normal. Trinidad, Dominica and St. Kitts were normal; Tobago and St. Croix severely dry; Grenada extremely dry; Barbados and St. Lucia abnormally dry; and St. Vincent, Antigua, Anguilla and St. Maarten moderately dry. Read more….

Headline Impacts

Reports from Jamaica have indicated that since December it has cost approximately USD$3000 per month to truck water to residents in Claredon affected by the ongoing drought.
The Gleaner (July 8th, 2014)

April-May-June (AMJ) Rainfall Summary

For the three month period, rainfall in the islands of the eastern Caribbean were normal to below normal, apart from St. Croix that was abnormally wet. Trinidad was normal to abnormally dry; Tobago, St. Lucia and Dominica moderately dry; Grenada and St. Vincent extremely dry; Barbados severely dry; Antigua and Anguilla abnormally dry; and St. Kitts and St. Maarten normal. Conditions in Guyana ranged from moderately wet in the west to exceptionally dry in the east. Aruba was severely dry, but Puerto Rico was normal. Rainfall in Jamaica ranged from moderately wet in the west to moderately dry in the east. Normal rainfall was observed in Grand Cayman, while Cuba's western areas were abnormally wet and the

We all know drought in the Caribbean region is a reality. Many countries are affected. You know there is a problem when someone publishes a regular bulletin about the topic.

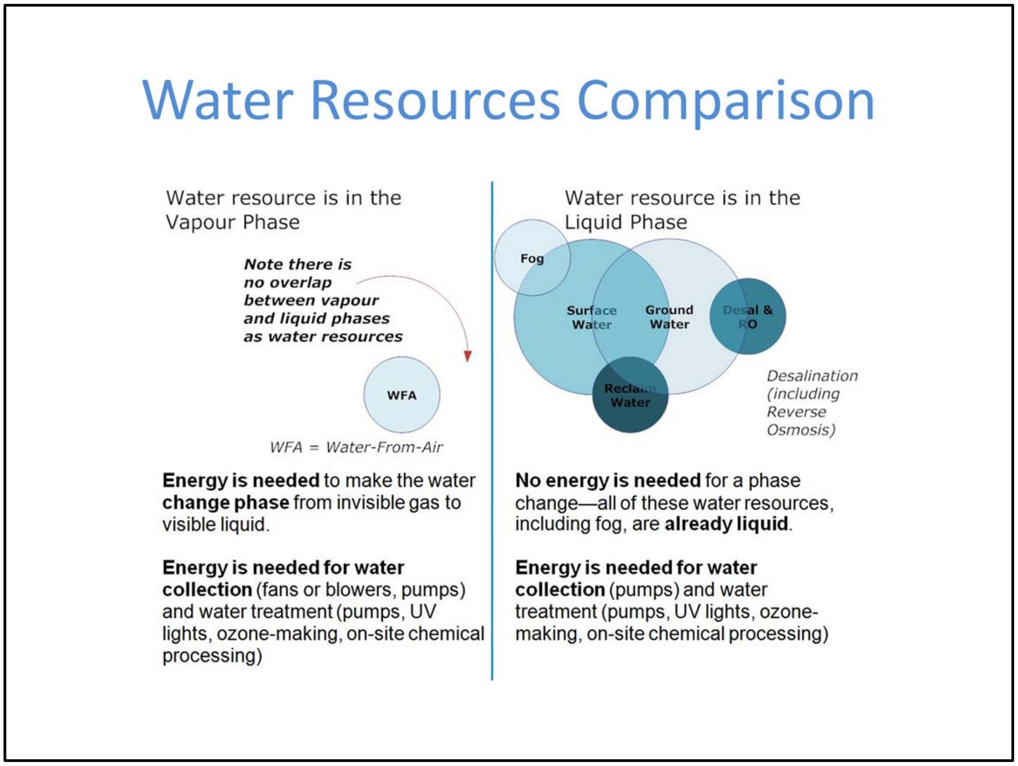
Solutions include Integrated Water Resource Management. Things to look at include: Have all the available water resources in the region been considered? Have all practical conservation measures been taken?

Water-from-air, obtained using mechanical dehumidification or desiccant technologies is a water resource still unfamiliar to many water resources professionals.

Why get water directly from the air?

- For regions with a scarcity of liquid water sources:
  - Population growth (plus tourism) exceeded capacities of surface and groundwater sources
  - Not meant to compete with ample sources of liquid water, although polluted or contaminated, that can be treated by standard filtration and chemical methods

The specific humidity of the surface air in the Caribbean region ranges from 12 to 20 grams per kilogram of moist air depending on location and season. Right now, in October, the outdoor air here surrounding Paradise Island would yield about 19 grams of liquid water for every one cubic metre of air processed by a dehumidifier. This is plenty for operating water-from-air machines. So why would we want to get water directly from the air? [Summarize the slide contents].



Here is an overview of the water resources available to us. The water-from-air resource is unique in being in the vapour or gas phase which means a relatively high amount of energy is needed to access the resource. Note that fog is not included in the water-from-air resource in this presentation.

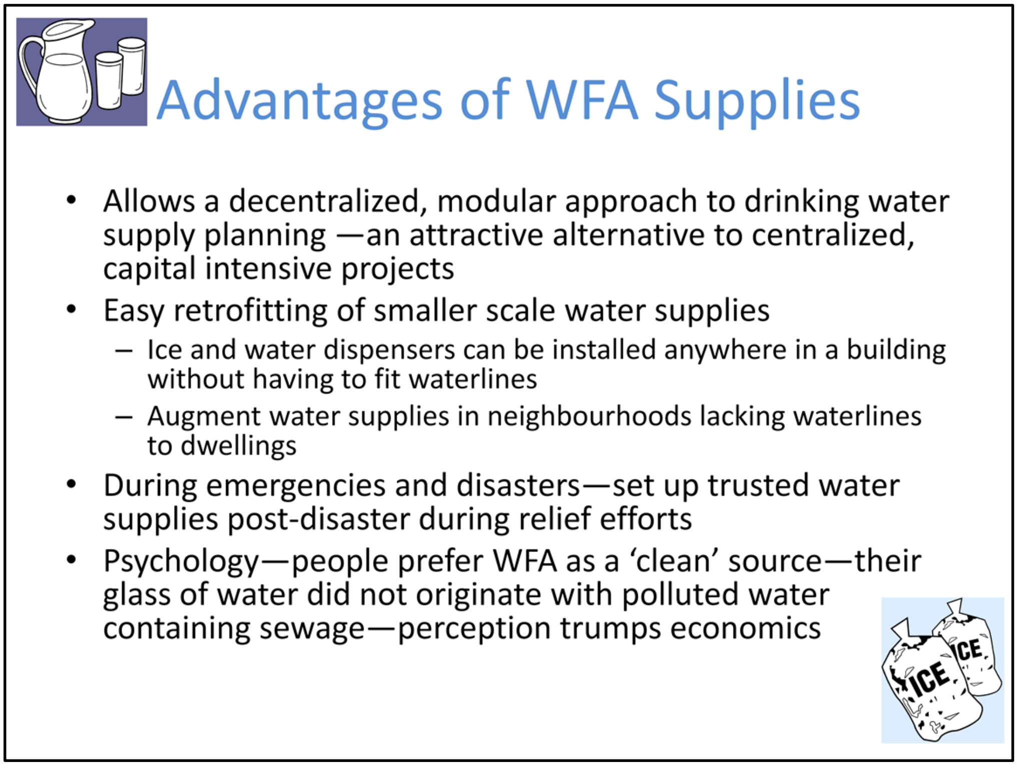
WFA Niche Applications

Water-from-air machines have the capacity to meet a variety of clean water demands year-round in tropical regions.

Application	Water use (L/head/day)
Individuals	15–25
Schools	15–30 L/pupil/day
Hospitals (with laundry facilities)	220–300 L/bed/day
Clinics	Out-patients 5; In-patients 40–60
Livestock: large (cattle)	20–35
Livestock: small (sheep, pigs)	10-25
Greenhouse: Tomato plant (mature)	1.2–2.5 L/plant/day

A 2,500 L/day processor of atmospheric water vapour in Belize City that Canadian Dew Technologies Inc. commissioned for a client in 2006.

I like to say that water-from-air is a technology meant for various niche roles in tropical regions when and where decentralized, distributed water points make economic sense.



The key words relating to the advantages of using the water-from-air resource directly include: decentralized, modular and mobile emergency water supply.

Another advantage is:

- No salt content. Dr. Eijkmans, at an earlier session at this conference, highlighted the problem of residual salt content (up to 250 mg/L) in reverse-osmisis (RO) water that is sent to drinking water taps—implicated in cardio-vascular diseases (CVDs)—a hidden societal cost.

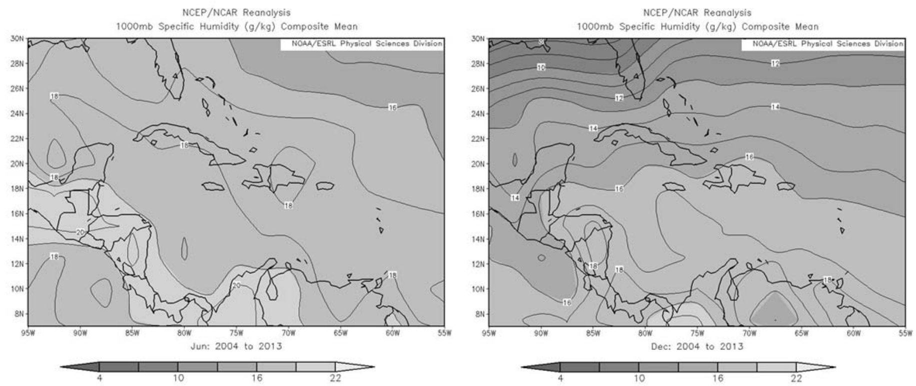
A further advantage is:

- Compared to RO, water-from-air is a simpler mechanical system operating at atmospheric pressure, not high pressure. The only pressure above atmospheric is 30 psi associated with pumping water through the water treatment module.

Caribbean water-from-air resource

Composite mean specific humidity for the ten months during 2004 to 2013

June **December**

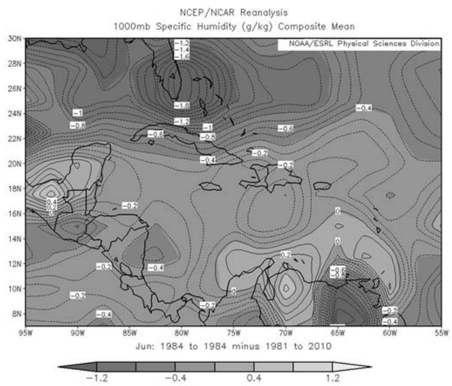


Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

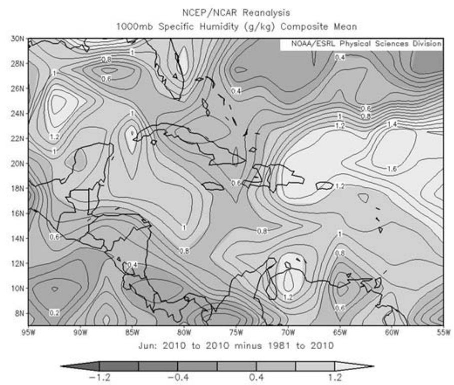
These maps quantify the Caribbean's water-from-air resource during the solstice months of June and December. The specific humidity fields for the ten other months of the year would be intermediate to the fields you see here. Note how the water-from-air resource increases the closer to the equator you go. The resource is less in the Northern Hemisphere winter, especially as you approach the mid-latitudes, like here in the Bahamas.

Drought and the water-from-air resource

Net specific humidity when the climate normal mean was subtracted from the June 1984 drought month mean



Net specific humidity when the climate normal mean was subtracted from the June 2010 drought month mean



Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado from their web site at http://www.esrl.noaa.gov/psd/; NCEP Reanalysis dataset (Kalnay, E. and Coauthors, 1996).

A couple of tests indicated that drought periods do not affect seriously the amount of water available in the atmosphere. The net difference in the specific humidity fields is close to zero for the result of subtracting the climate normal mean field from the drought month mean.

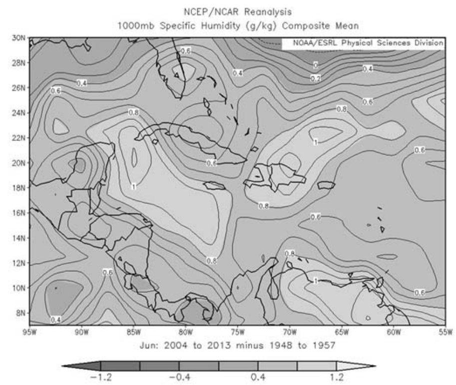
June 1984 has mostly small negative values. This may indicate a slight decrease in the water vapour resource during the drought period.

On the other hand, June 2010 has mostly small positive values. This may indicate a slight increase in the water vapour resource during the drought period.

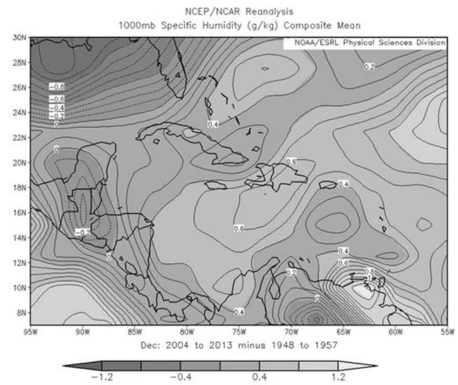
Explanations for these interesting observations are outside the scope of this presentation.

Climate change and the water-from-air resource

Net specific humidity composite mean field for June when the field for 1948–1957 was subtracted from the field for 2004–2013



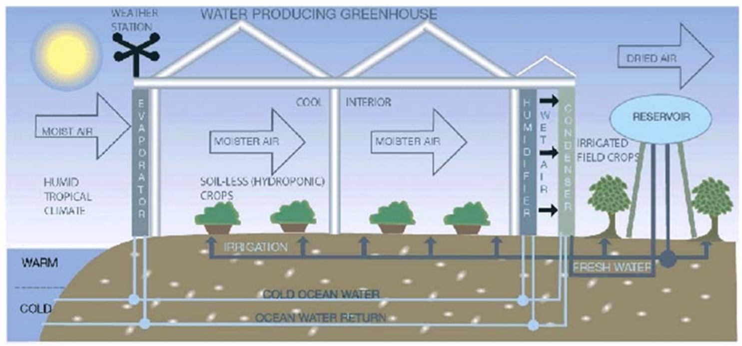
Net specific humidity composite mean field for December when the field for 1948–1957 was subtracted from the field for 2004–2013



Similarly , climate change does not appear to have affected the water-from-air resource in any meaningful way. The net specific humidity composite mean field values for June and December are close to zero when the field for decades-ago 1948 to 1957 is subtracted from the recent period 2004 to 2013.

For both June and December we observe a slight increase in the water vapour resource over the last 50 to 60 years. This agrees with the observed planetary warming trend. A warmer atmosphere can hold more water vapour.

Case Study—Turks and Caicos Islands



Our first case study is about a large-scale 200,000 L/d water-from-air system using a natural coolant source to chill coils to condense water. In 2003, the people living on the island of Grand Turk, TCI were importing 100% of their food and had inadequate, unreliable fresh water supplies. Could water-from-air technology provide a solution? I participated in answering this question during 2001–2003 when I was the scientific/technical consultant to a Canadian International Development Agency (CIDA)-supported project which confirmed through modeling the technical feasibility and financial and commercial viability of a 200,000 L/d water-from-air greenhouse on the island.

Climate, Refrigeration Load, and Water Production Model—**WaterProducer-Greenhouse™ System**

Grand Turk, Turks and Caicos Islands

Elevation*.. 2 metres above sea level Lat: 21° 26' N

Standard atmosphere........................... 1.013 bar Long: 71° 08' W

Delta T is adjusted to simulate natural coolant constant temperature

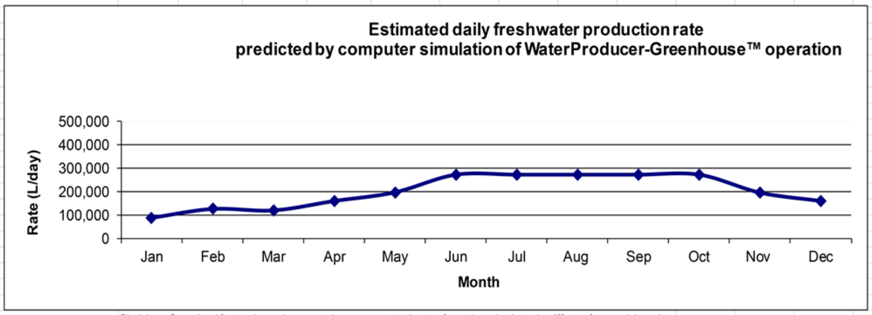
Delta T = air temperature - leaving air (coolant) temperature

Model Input value

MaximizeWater Production

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Calibration
Airflow, cfm	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000
Airflow, m^3/s	382	382	382	382	382	382	382	382	382	382	382	382	382
Temperature*, db, °C	24	24	25	25	27	28	28	28	28	28	26	25	27
Relative Humidity, RH, %	69%	74%	69%	74%	70%	74%	74%	74%	74%	74%	74%	74%	60%
Wet bulb, wb, °C	19.9	20.6	20.8	21.5	22.8	24.3	24.3	24.3	24.3	24.3	22.5	21.5	20.9
Air pressure, bar	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
Delta T (°C) - adjusted for leaving air (coolant) temp = 15°C	9.0	9.0	10.0	10.0	12.0	13.0	13.0	13.0	13.0	13.0	11.0	10.0	11.7
Leaving air (coolant) temp, db, °C	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Leaving RH, % - conservative setting	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dew-point*, t_4, °C, of entering air	18.0	19.1	18.9	20.0	21.1	22.9	22.9	22.9	22.9	22.9	21.0	20.0	18.3
Total cooling capacity, Tons	1,920	2,228	2,308	2,634	3,194	3,938	3,938	3,938	3,938	3,938	3,054	2,634	2,348
water vapor density, g/m^3	15.1	16.2	16.0	17.1	18.1	20.2	20.2	20.2	20.2	20.2	18.1	17.1	15.3
Estimated water production, Litres/day	**89,121**	**126,807**	**120,793**	**160,776**	**197,931**	**273,255**	**273,255**	**273,255**	**273,255**	**273,255**	**196,453**	**160,776**	**99,164**

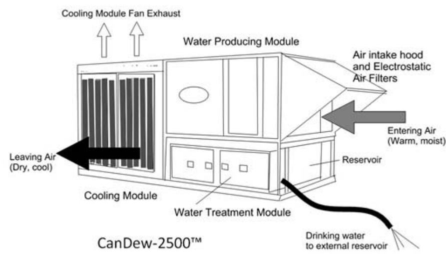
* Climate data and altitude input to model (various sources, believed to be accurate)



Disclaimer: Operational factors beyond our control may cause actual w ater-from-air production to be different from model results.

A monthly model of the WaterProducer-Greenhouse™ system water production is shown in this slide. Although the first installation remains to be built, the modeling results for this chilled coil (deep saline groundwater coolant) are instructive. At latitude 21°N, seasonal variations are apparent in the water vapour density (which is the water resource) and therefore daily water production. Production is highest during the high sun season and lowest during the low sun season. Reservoirs are needed to store water to, in effect, even out the flow for a steady consumption rate.

Case Study—Belize City



In January 2006 I commissioned two medium-scale 2500 L/day water-from-air machines my client had shipped to a business in Belize City.

By the way, has anyone here in the audience seen any installations in the Caribbean region of machines similar to this? [show of hands revealed none had; there were about 30 people in the audience].

Here you can see the various parts of the machine…[refer to slide].

Climate, Refrigeration Load, and Water Production Model—2500 L per day machine

Belize City, Belize

Elevation.......................... 4 metres above sea level | Lat: 17° 32' N | Long: 88° 18' W

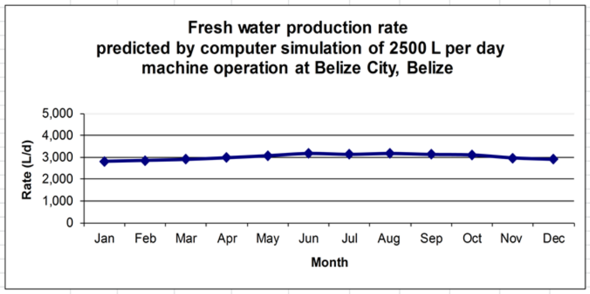
Standard atmosphere.......................... 1.013 bar

Controller setpoint used to adjust Delta T.

Model Input value

Climate data from *www.weatherbase.com*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Airflow, cfm	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Airflow, m^3/s	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Temperature*, db, °C	**23**	**24**	**26**	**27**	**28**	**28**	**28**	**28**	**27**	**26**	**25**	**24**
Relative Humidity, %	**84%**	**83%**	**81%**	**80%**	**80%**	**84%**	**84%**	**84%**	**86%**	**86%**	**85%**	**85%**
Wet bulb, wb, °C	21.0	21.8	23.4	24.2	25.2	25.8	25.7	25.8	25.0	24.2	23.1	22.1
Air pressure, bar	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
Delta T (°C) - adjusted for ≤ 40 Tons and leaving air temp ≥ 5°C	15.5	15.0	14.5	14.5	14.0	13.0	13.0	13.0	13.0	13.5	14.0	14.5
Leaving air temp, db, °C	7.5	9.0	11.5	12.5	14.0	15.0	15.0	15.0	14.0	12.5	11.0	9.5
Leaving RH, % - conservative setting	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Req'd Total capacity, Tons	39.9	39.6	39.2	39.8	39.9	39.6	39.3	39.6	39.3	39.8	39.3	39.4
Total capacity, kW	140	139	138	140	140	139	138	139	138	140	138	139
Sensible capacity, kW	60	58	56	56	54	50	50	50	50	52	54	56
Difference: Latent capacity, kW	80	81	82	84	87	90	88	90	88	88	84	82
Expected water prod'n, L/d	**2,813**	**2,855**	**2,900**	**2,976**	**3,066**	**3,168**	**3,128**	**3,168**	**3,124**	**3,103**	**2,969**	**2,901**
Efficiency of water recovery from air	58%	56%	52%	51%	49%	49%	48%	49%	50%	52%	53%	55%



Energy cost of water — **Average** **0.36 kWh/L** (based on operation all year)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Voltage (V), 3 phase	460	460	460	460	460	460	460	460	460	460	460	460
Average current (A)	70	70	70	70	70	70	70	70	70	70	70	70
Power (W)	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565
Time (hours)	24	24	24	24	24	24	24	24	24	24	24	24
Energy (kWh)	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
Energy cost of water (kWh/L)	**0.38**	**0.37**	**0.37**	**0.36**	**0.35**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.36**	**0.37**

The monthly model results are in this slide. Belize City is 17 degrees latitude north of the equator. Seasonal influence on water production was not as pronounced as in Grand Turk because the water from air resource is fairly constant through the year. Energy cost of the produced water was about as good as it can be with mechanical dehumidification—0.34 to 0.38 kWh per litre. The model represents a machine that is perfectly designed and adjusted. The model does not reference details of the machine's cooling coil materials, dimensions, or coil arrangement.

Before we leave this slide, let's note the January and February values for daily water production (about 2800 L/d) and energy cost of the water (about 0.38 kWh/L).

s/n 0001

Record Number	Date	Time Start	Time End	Entering Air Temp °C	Entering Air RH %	Airflow CFM	Discharge Air Setting °F	Coil temp °C	Leaving Air Temp °C	Leaving Air RH %	Daily Equiv. Production L/d	Energy Cost kWh/L
1	26-Jan-06	13:34:00	13:46:50	26.9	75	5085	41.0	not recorded	not recorded		2244	not recorded
2	26-Jan-06	14:38:30	14:50:45	27.4	77	5085	45.0	4.1	14.8	87	2351	not recorded
3	26-Jan-06	15:15:10	15:30:20	24.2	98	5085	50.0	8.9	12.3	99	1899	not recorded
4	27-Jan-06	10:46:00	10:58:35	26.0	81	7337	47.5	not recorded	not recorded	not recorded	2289	not recorded
5	27-Jan-06	11:04:00	11:15:18	26.2	81	7337	47.5	9.9	12.2	99	2549	not recorded
6	27-Jan-06	11:50:00	12:00:45	26.7	80	7337	47.5	10.0	12.7	99	2679	0.35
7	27-Jan-06	12:15:00	12:26:30	27.3	73	7337	47.5	10.7	13.1	99	2504	0.40
8	30-Jan-06	11:09:00	11:19:36	32.6	50	7337	47.5	12.6	13.4	99	2717	0.40
9	30-Jan-06	11:25:00	11:35:50	31.9	58	7337	47.5	12.0	13.1	99	2658	0.35
10	30-Jan-06	11:39:00	11:50:00	32.4	52	7337	47.5	12.6	13.5	99.0	2618	0.40
11	31-Jan-06	12:36:00	12:47:50	33.4	51	7337	47.5	11.9	12.5	99.0	2434	0.40
12	31-Jan-06	12:50:00	13:01:50	33.0	52	7337	47.5	11.8	12.4	99.0	2434	0.40
13	31-Jan-06	13:05:00	13:16:50	33.0	52	7337	47.5	11.8	12.6	99.0	2434	0.40
14	02-Feb-06	11:37:00	11:47:55	32.2	50	7337	47.5	11.4	12.3	99.0	2638	0.35
15	02-Feb-06	11:49:30	12:00:35	31.9	57	7638	47.5	11.6	12.4	99.0	2598	0.35
16	02-Feb-06	12:03:00	12:13:10	32.3	50	7638	47.5	11.4	12.4	99.0	2833	0.35
17	04-Feb-06	10:30:00	10:42:25	26.8	82	5286	45.0	6.8	7.6	99.0	2319	0.40
18	04-Feb-06	10:43:30	10:55:23	26.6	84	5286	45.0	7.0	7.3	99.0	2424	0.40
19	04-Feb-06	10:57:00	11:08:45	26.5	86	5286	45.0	6.9	7.3	99.0	2451	0.40

It is interesting to look at the actual data-logged observations, shown here, from the commissioning of a 2500 L/day machine in Belize City. The machine responded continually to fluctuations of entering air pressure, temperature, and water vapour density. The model results for January–February in the previous slide and these observations during late January–early February have similar values for water production rate and the energy cost of the water. So, the model can be relied on for guidance in planning deployment of machines in a region.

Lessons Learned

200,000 L/d
Grand Turk

- No existing similar design installation as a precedent;
- Limited access to risk capital;
- Resistance from water managers in 2003 to changing to an unfamiliar decentralized water distribution business model;
- Resistance from energy utility managers in 2003 to allowing wind, solar, and other energy alternatives to be used for projects within their region of jurisdiction; and
- Importing food and water to Grand Turk remains relatively easy in the short-term.

2500 L/d
Belize City

- Relatively high energy costs of USD 0.215 per kWh (in 2006);
- As might be the case in any country, there was inadequate entrepreneurial vision and advance business planning; and
- My client had limited funds available to sustain demonstration site operation until a local market developed for the product water or the machines themselves for other sites in Belize and neighbouring countries.

Lessons learned were from two entirely different scales of WFA production. Grand Turk was a 200,000 L/d system. Belize City was a 2500 L/d system although several of these could be combined for greater capacity.

[Refer to slide]

Conclusion

As resident and tourist populations grow in Caribbean countries, water managers now know they have another reliable water source to tap: water-from-air.

Whether or not this actually happens depends on:

- Bold, early adopters

  If you want to understand something, try to build [use] it.
  —Bob McDonald, Host of CBC's Quirks & Quarks

- Scientific and technical knowledge and support

  To measure is to know.
  —Lord Kelvin (Sir William Thomson)

Water-from-air production rate test, Belize City

Public health official collecting sample for water quality test, Belize City

[Refer to slide]. I admire these two statements by a couple of smart people… That concludes this part of my presentation. I suggest we allot about 10 minutes for comments or questions. After that, during the remaining minutes of this session Nigel will make available for you three things: Handouts for the presentation you just saw; Country specific brochures about the water from air resource in the Caribbean; Executive summaries about the water-from-air greenhouse project

So, are there any questions or comments? [There were two questions from the audience]

1. Does anything need to be added to or subtracted from the water?

Answer: Subtraction: The water needs to be treated to kill micro-organisms. Addition: Nothing needs to be added to the water. Sometimes minerals are added to the water but this is not essential because people get their minerals from the food they eat, not the water they drink.

2. How is the cost of the water calculated?

Answer: The complete way to calculate the cost of a litre of water is to do a proper financial analysis which accounts for the total volume of water which will be produced over the lifetime of the machine. Capital and operating costs must be accounted for. Electricity costs are a major part of the operating cost.

- Nigel has now set up the handouts and so on so feel welcome to take what interests you.