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RACE AGAINST TIME:

ADDRESSING THE CHALLENGE OF RESOURCE SCARCITY

"The past four centuries of magnificent progress were made possible by two non-repeatable achievements: (a) discovery of a second hemisphere, and (b) development of ways to exploit the planet's energy savings deposits, the fossil fuels…Today mankind is locked into stealing ravenously from the future. By our sheer numbers, by the state of our technological development…we have made satisfaction of today's human aspirations dependent upon massive deprivation for posterity."

WILLIAM CATTON, OVERSHOOT: THE ECOLOGICAL BASIS OF REVOLUTIONARY CHANGE[1]

There has been no lack of attention by great thinkers to the problem of scarcity over time. From the time of Malthus, economists and philosophers have grappled with the seemingly intractable problem of sustainability – that is to say, how can we create a sustainable society, given the seemingly impossible task of reconciling the Earth's finite resources with mankind's infinite appetite and ambition?

The challenge certainly did not escape the attention of William Catton, author of the classic ecology treatise "Overshoot." One of his most enduring metaphors is the comparison of mankind's behavior to that of yeast cells when added to a wine vat. When introduced, the yeast cells find an environment with abundant, but ultimately finite sugar resources. Unlike other interactions in nature, the yeast cells do not seek equilibrium in this new environment. They instead expand uncontrollably, voraciously consuming everything in their path. Inevitably the yeast cells die out, starving as all available resources are exhausted.

So far, humanity's reaction to the abundant but exhaustible resources in nature has been no different. Our population and per capita resource consumption has grown explosively as our technology has advanced, and today our demands increasingly test the capacity of our environment. But the picture is not as dark as it may appear. Many forward-thinking companies are applying an unprecedented amount of innovation and ingenuity to these problems, and they are developing a wide range of pioneering technologies and solutions within the water, energy, agriculture and other sectors that may be able to overcome the scarcity challenges we face.

In this paper, we will discuss the looming scarcity challenges for three of modern society's most basic staples – oil, water and food – as well as the market-based solutions being deployed to address those challenges. As investors we are enthusiastic about the substantial market opportunities available to these companies, and as global citizens, we believe that society's prospects are certainly improved by the sorts of solutions outlined in these pages.

An oil field in Namibia is reclaimed by the desert

Oil Scarcity

"An energy crisis is coming, likely to be triggered by oil. Demand is expected to grow on an annual basis by at least one million barrels per day, driven by the developing economies of the world and by a growth in transportation as we go from one billion cars today to two billion cars in 2050. As demand grows in the next decade, we will not have the oil production capacity we will need to meet demand. Supply will then have to ration demand, and prices will skyrocket – with the likely outcome of bringing the world's economy to its knees . . . The $140-per-barrel oil price of three years ago was not an aberration, it was a warning."

JOHN B. HESS, CHAIRMAN, AMERADA HESS CORPORATION[2]

THE OIL SHOCK OF 2007-2008, IN WHICH OIL PRICES PEAKED AT $145/BARREL, WAS VIEWED BY MANY AS A WARNING THAT THE GLOBAL BALANCE OF ENERGY SUPPLY AND DEMAND HAD REACHED A TIPPING POINT. WHILE THE RECENT ECONOMIC RECESSION BROUGHT A TEMPORARY PRICE REVERSAL, OIL PRICES RECOVERED WITH THE GLOBAL ECONOMY, AND ONCE AGAIN CROSSED THE $100/BARREL THRESHOLD IN 2011, SPURRED BY SEVERE POLITICAL INSTABILITY IN THE MIDDLE EAST.

WE CAN'T ANSWER THE QUESTION OF IF, OR WHEN, GLOBAL OIL PRODUCTION PEAKED, OR WILL PEAK, IN THIS NEWSLETTER. BUT WE KNOW THAT BY DEFINITION, OIL IS GROWING SCARCER EVERY DAY, AND THE PRICE MOVEMENTS IN THE OIL MARKETS OVER THE PAST DECADE CERTAINLY SUGGEST A MARKET WHERE SUPPLY IS BEING OVERTAKEN BY DEMAND. SOME OF THE FACTORS AT PLAY:

1) Rising production costs

Marginal production costs are very important drivers of energy supply – companies will only produce the "next" barrel of oil if they can make a profit. And the marginal cost of oil production is on the rise. While established, onshore giant oil fields in Russia and the Middle East can produce oil profitably near a price of $20/barrel, deepwater production in the Gulf of Mexico and Brazil becomes profitable at $65/barrel, and oil from tar sands and other unconventional sources only become profitable at $80-$100/barrel. And due to ever-rising demand, these more expensive sources of oil are becoming a bigger part of the equation.

The Sugarloaf, Tupi and Jupiter fields discovered off of Brazil recently are a good example. As reported in *The Economist*, these fields in the Santos Basin promise tens of billions of barrels of oil, but the oil rests about 7 km beneath the seabed under a 2km layer of salt, at much higher temperatures and pressure than a conventional deepwater field. Getting this "sub-salt" oil to the surface will require innovative submarine technology, robotics technology, new kinds of material to withstand the pressure as well as the corrosive sub-salt conditions – needless to say, oil from this source will prove expensive to extract.[3] But if the trend of rising demand does not change, these sorts of sources will be increasingly important in filling our demand, and therefore setting a much higher floor for oil prices.

2) Declining production from existing fields

Starting in 2004, the annual growth in total world oil production slowed significantly. In 2010, the International Energy Agency (IEA) declared that the world had actually reached its likely peak in conventional crude oil production in 2006; going forward, the IEA projects world production to remain at an "undulating plateau" of 68-70 million barrels per day.[4] (This figure does not include unconventional fuel sources or natural gas liquids.)

This plateau will "undulate" due to the interaction of two forces – the amount of production coming on line from new fields, and the rate of decline in production from older fields, particularly the 500 or so giant oil fields which dominate the current supply picture. In 2005, giant oil fields contributed approximately 60% of world oil production, with the biggest 20 fields alone responsible for about 25%; the majority of these fields are now over 50 years old and in a state of production decline.[5]

Even worse, mature oil fields exhibit a well-established accelerating decline curve. In other words, once a field "tips" into decline, it will decline faster and faster over time. Because the average age of the world's population of giant oil fields is increasing every year, we are getting closer to a period when decline in many of these fields begins to accelerate.

Because of the lack of public data on many Saudi Arabian and other Middle Eastern oil fields, it is impossible to definitively state a global production decline rate. Cambridge Energy Research Assoc. (CERA), a leading energy consultancy, estimated a 4.5% decline rate in a recent study,[6] while other sources, such as oil-services titan Schlumberger's CEO Andrew Gould, suggest decline rates as high as 8%.[7] If CERA's more conservative assumption is correct, it would mean that we would need to bring on line 3-4 million barrels per day of new oil every year just to maintain current supply; if the higher assumptions are correct, that need would rise to 6-7 million barrels per day. To put that in context, Oil Megaprojects, a collaborative data project, reports that in 2010, 4.9 million barrels per day were brought on line, and that in 2011, 3.2 million barrels per day are expected to come on line.[8]

A key takeaway from these supply trends: day by day, our stash of $20/barrel is running out, and we are replacing it with $100/barrel oil. However long the era of oil might be, the era of cheap oil is certainly going to be much shorter, and may already be at an end.

3) Emerging Market Demand

Constraints on global oil supplies wouldn't be nearly as distressing if we weren't also facing rapid growth in demand for liquid fuels. In particular there has been explosive demand growth in emerging markets, even in the face of rapidly rising prices. According to Morgan Stanley, gasoline demand in China has increased 41% since 2005, despite prices having risen by 122%. In India, over the same period, prices rose by 20% and demand rose by 29%.[9]

In 2009, McKinsey & Co. published a study entitled "Exploring global energy demand," which examined various oil demand scenarios through the year 2020, taking into account key variables such as energy productivity, GDP growth, fuel efficiency standards, and growth in electric vehicle sales. The most "optimistic" scenario – meaning, the scenario projecting the lowest growth in demand – assumed a very severe and protracted economic downturn as a result of the 2008-2009 debt crisis; fuel efficiency standards across the globe increasing to match European Union standards; and massive growth in electric vehicles, reaching 50% of all vehicle sales by 2020. Even under this somewhat unlikely scenario (the economy has already performed more positively than the assumption in this scenario), demand in emerging economies is still projected to increase by 11 million barrels per day, and overall global demand is projected at over 95 million barrels per day by 2020.[10]

The above factors combine to form a stark illustration of oil scarcity: our best efforts to grow oil supplies won't be able to keep up with the growth in demand from rising economies for much longer.

Supply-Based Solutions

Unfortunately, there is no magic solution to radically change the overall oil supply. The industry is already actively exploring deepwater sites all over the world; tar sands are being exploited; crops to be converted into ethanol – wisely or unwisely – are being grown and harvested on a large scale. We can't accurately predict whether tomorrow's newspaper will report huge, easy-to-access oil discoveries, or none at all, but we do know that there is a multi-decade trend pointing to a decreasing amount of newly discovered oil. And we can say definitively that there is no new technology that will change the amount of oil that we have left in the ground.

The industry is, however, pushing forward with innovations that improve the efficiency of extracting that oil. Enhanced oil recovery (EOR) refers to a range of techniques designed to increase the percentage of oil that can be recovered from a partially depleted oil field. Steam injection has been in use since the 1960s, while currently the most common form of EOR is gas injection – specifically CO2 injection. CO2 injection has proven very effective in partially depleted wells, and the technique also offers significant

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An electric vehicle "fills up" its batteries at a charging station

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promise as a carbon capture and storage (CCS) solution, if and when there is enough economic incentive for third parties to collect CO2 from emitters for EOR usage. In fact, EOR and CCS are more economically intertwined than might be apparent at first glance; the Department of Energy (DOE) has estimated that full use of CO2 EOR techniques in the U.S. could lead to an additional 240 billion barrels of recoverable oil resources; but such widespread deployment would require large volumes of CO2 that could only be achieved through capture from commercial and industrial emitters.[11]

Demand-Based Solutions

While there is little we can do to impact the supply of oil, there are plenty of solutions already available today to significantly impact oil demand. Transportation solutions which focus on more efficient use of gasoline, as well as substitutes for gasoline, have tremendous potential to reduce oil scarcity. To name a few:

- **Natural gas vehicles (NGVs)** Vehicles using natural gas typically emit 70%-90% less carbon monoxide and 20%-30% less carbon dioxide than the petroleum-based vehicles they replace. More relevant to the problem of oil scarcity: they do not use oil. NGVs are becoming more popular as the long-term cost spread between oil and natural gas widens; widespread consumer adoption is still a long-term vision, due to the lack of fuel station infrastructure, but for commercial fleets (which often use their own fueling stations), NGV conversion is gaining traction.

- **Electric vehicle technology** Plug-in vehicle technologies offer significant long-term promise in the quest to reduce oil dependence, but like natural gas vehicles, the lack of fueling infrastructure – or more accurately, charging infrastructure – is a primary impediment to adoption. Additionally, electric vehicles face rather firm limits in terms of range and performance due to the constraints of current battery technology. The Chevy Volt and Nissan Leaf may meet or surpass their manufacturers' expectations, but much more technological progress is required before electric vehicles can truly compete in the market.

- **General efficiency gains in engines** – For over 20 years, automakers have had the technology available to make cars with much better fuel economy; instead that technology was used to keep fuel economy flat while doubling engine power and increasing vehicle weight. Increasingly, technology is being redeployed away from power and toward efficiency – ranging from newer technologies like hybrid systems and stop/start systems, to more liberal use of turbochargers and other established components. Part and component manufacturers with catalogs well-positioned for this shift have seen success in recent years.

- **Rail transport/intermodal transport** Conventional wisdom states that rail transport is more energy efficient than truck transport. That is generally correct – the average train moves freight at 400 ton-miles per gallon while the average truck is closer to 130 ton-miles per gallon. However, commercial trucking fleets can be upgraded significantly; a study from the Rocky Mountain Institute reveals that state-of-the-art technology can increase the ton-mileage of the average class 8 truck to 275 ton-miles per gallon.[12] Additionally, traditional rail transport often requires temporary storage of cargo due to scheduling, making it useless for perishable cargo or for companies utilizing just-in-time logistics. Intermodal transport – an integration of rail for long-haul and trucking for last-mile delivery and pickup – offers the best of both worlds. The EPA estimates that intermodal shipping can cut fuel usage by 65% versus truck transport for shipments greater than 1,000 miles;[13] this fact has been a primary driver of the growth of intermodal shipping in recent years. □

Women in Ethiopia on their daily water-carrying trek for their families

Water Scarcity

"Children of a culture born in a water-rich environment, we have never really learned how important water is to us. We understand it, but we do not respect it."

--WILLIAM ASHWORTH, "NOR ANY DROP TO DRINK," 1982[14]

"Water is the oil of the 21st century."

–ANDREW LIVERIS, CEO DOW CHEMICAL, 2008[15]

READERS ARE LIKELY FAMILIAR WITH THE ONGOING DEBATE OVER THE CONCEPT OF "PEAK OIL" – MEANING, THE QUESTION OF WHEN GLOBAL OIL PRODUCTION WILL REACH AN APEX AND BEGIN A STEADY DECLINE, OR WHETHER IT ALREADY HAS. PERHAPS LESS FAMILIAR IS THE EMERGING DISCUSSION ABOUT A FAR MORE DANGEROUS SITUATION – THAT OF "PEAK WATER." THE WORLD HAS ALREADY SURPASSED A CRITICAL TIPPING POINT IN THE WATER SUPPLY/ DEMAND EQUATION; WORLDWIDE DEMAND FOR WATER NOW EXCEEDS SUSTAINABLE SUPPLY, AND BY 2030, MCKINSEY EXPECTS WATER SUPPLIES TO FALL SHORT OF GLOBAL DEMAND BY 30-40% ANNUALLY.[16] THIS IS A TRULY HARROWING PROJECTION – MORE THAN ANY OTHER SCARCITY ISSUE, WATER SCARCITY IS THE IMPASSABLE OBSTACLE TO BASIC HUMAN PROGRESS AND, IN MANY PARTS OF THE WORLD, A LACK OF WATER VERY CLEARLY REPRESENTS AN IMMEDIATE THREAT TO HUMAN SURVIVAL. SOME OF THE FACTORS CONTRIBUTING TO THIS CHALLENGE INCLUDE:

1) Uneven distribution

Brown Advisory's 2010 white paper on water scarcity, "Please Mind the Gap," provides a good breakdown of global water supplies. Once the inaccessible and nonrenewable water sources – glacier ice, salt water, lake water, etc. – are removed from the supply equation, only 0.0007% of the Earth's water is actually available in a sustainable manner.

While this may seem like a tiny number, it actually isn't a problem by itself. The problem is that the water is concentrated in one set of locations (primarily the Northern Hemisphere) and global population is increasingly concentrated in another set of locations (primarily the Southern Hemisphere). Globally, one-third of sustainable supplies can be found in Brazil, Russia, Canada, and the United States – nations whose populations represent only 10% of the world's population. In contrast, China is attempting to support 20% of the world's population on 7% of the world's water supply; India is similarly responsible for 17% of global population with access to only 4% of global water supplies.[17]

This situation has been exacerbated by poor environmental policies and various economic factors, but the end result is that, according to the United Nations (U.N.), over 1 billion people around the world live

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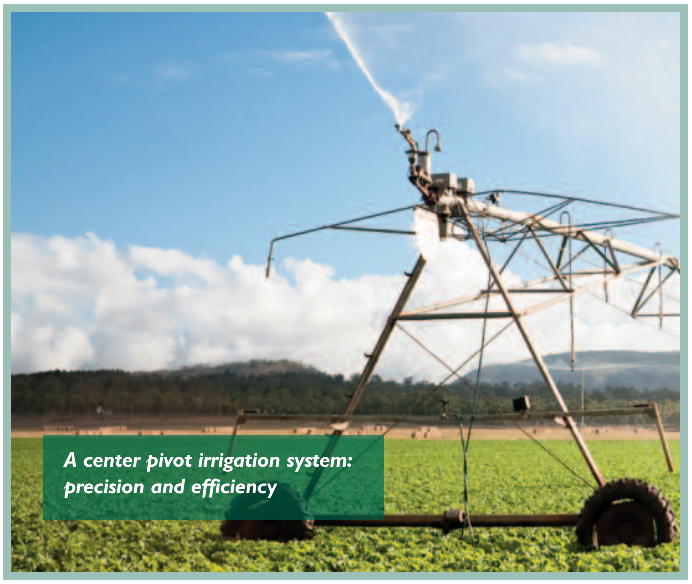
in physical water scarcity conditions (insufficient water supply for the population), and an additional 1.6 billion live in economic water scarcity conditions (sufficient supplies, but insufficient capital or infrastructure to distribute to end users).[18] That's over 40% of the world's population.



A center pivot irrigation system: precision and efficiency

Water filtration systems can be used at a community level

2) Emerging market demand

The world's population is forecasted to grow to 9 billion by 2050. Given that the U.N. estimates that we are already using more than half of the world's accessible freshwater—from rivers, lakes and aquifers—it's easy to see how simply inflating our water use proportionally would be scary enough. But that doesn't tell the whole story:

- Almost all of that growth is expected to take place in Asia and Africa, much of it in areas that are already water stressed as mentioned above. In addition to China and India, the ongoing population boom in the Middle East and North Africa (MENA) is a significant concern; the population in the MENA region was 135 million in 1970, and is expected to exceed 550 million by 2050; this population growth represents a mounting crisis for a region with less than 1% of global water resources.[19]

- At the same time, the standard of living is increasing in many emerging economies in the Southern Hemisphere. While that trend is a positive development for many individuals, in the aggregate it is very dangerous; increased living standards historically translate into increased demand for water. The U.N. deems that the daily minimum per capita water requirement for an individual is about five gallons, while a typical American uses closer to 100-175 gallons per day.[20] Additionally, higher living standards bring demand for better nutrition and for animal protein in particular. This becomes another significant water challenge; it takes 140 gallons of water to produce a pound of cereal grain, but 1,800 gallons to produce one pound of beef.

Combining these factors, the U.N. warns that in 2050, **two-thirds of the world's population** may live under water stress conditions.

3) Agricultural water use/ productivity issues

It may come as a surprise that agriculture accounts for 70% of global water consumption, and up to 95% in some developing countries.[21] Because of this, the productivity, or lack of productivity, of water use in agriculture is perhaps the most significant factor driving global water scarcity.

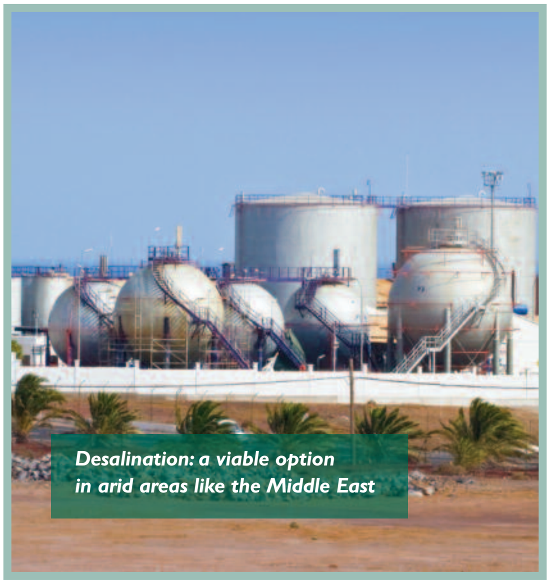
Best-of-class agricultural practices have become very sophisticated, but these techniques are in no way deployed across the world. The International Water Management Institute suggests that "75% of the additional food we need over the next decades could be met by bringing the production levels of the world's low-yield farmers up to 80% of what high-yield farmers get from comparable land," particularly in water-scarce regions such as Sub-Saharan Africa and parts of South Asia and Latin America. Better water management plays a key role in bridging that gap. The vast potential for improvement is the good news; the bad news is that inaction will result in a 70%-90% increase in water consumed by crop growth by 2050, an increase that the world simply cannot support in a sustainable manner.[22]

Supply-Based Solutions

As noted in *National Geographic* several years ago, "All the water that will ever be is, right now."[23] We can't permanently deplete our water stocks, but we can't increase them either.

There are, however, solutions in the market that can convert unusable water into usable water:

- **Desalination** Turning ocean water into fresh water has always been an attractive option in water-stressed coastal regions. Traditional desalination efforts focus on boiling seawater and collecting the resulting freshwater as it condenses, typically in low-pressure chambers to lower required boiling temperatures. This process, referred to as vacuum distillation, accounts for the vast majority of worldwide desalination volume. It is very energy-intensive and therefore expensive; however these plants require little in the way of mainte-



Desalination: a viable option in arid areas like the Middle East

nance, and are popular in the Middle East (especially in Saudi Arabia, where fuel costs are very low). A newer process called reverse osmosis is far more energy efficient and is beginning to gain traction in the market; reverse osmosis uses high pressure to filter seawater through a specialized membrane that traps all mineral content and only allows fresh water to pass through. Other research in desalination is investigating the use of forward osmosis – in which water is slowly pulled through a membrane to a solution mixed with ammonia salts on the other side (water naturally flows to higher salt concentrations) – and the use of nanotechnology to create, in theory, far more effective membrane materials.

- **Recycling / reclaiming water** The other main supply side solution is using reclaimed, or recycled, water for certain applications. This can take many forms. Processed water from wastewater treatment plants has long been used to recharge groundwater by re-injecting it into an aquifer. Additionally, reclaimed water is now increasingly being used in non-potable end-use applications. Industrial water firms are providing everything from rainwater and runoff capture to industrial purification systems, creating a reclaimed water supply for customers to use for irrigation, industrial production, or even fire suppression. On a smaller scale, residential dual piping systems (also known as greywater systems) can recycle water that has been used in sinks or washing machines, or captured from rainwater, for uses such as flushing toilets or irrigation.

Many areas, especially in developing countries, lack the massive infrastructure necessary to provide clean drinking water. In these areas, point-of-use water treatment systems at either the community or household level can greatly improve quality of life. Such systems can range from simple filtration to more complex disinfection. For example, systems are sold in India to provide water filtration in homes without a reliable source of electricity, and similarly there is a growing market in China for home water purification systems. In developed countries, households may choose a point-of-use system to improve the quality of water, such as the water filtration pitchers that have gained a foothold in the U.S. in recent years.

Demand-Based Solutions

Reducing water demand must focus on using water more efficiently. As noted above, agriculture accounts for 70% of global water consumption and there is ample opportunity to improve efficiency in this arena, primarily through efficient irrigation. Simply covering irrigation channels to prevent evaporation can save a lot of water, as can switching from traditional surface irrigation, gravity or "flood" irrigation which is only 60% efficient, to more sophisticated techniques. Center pivot and lateral move systems are able to deliver water from overhead where needed rather than flooding the whole field, and are often tied to agricultural GPS systems for more exact water delivery. Drip irrigation systems deliver water directly to plants from below for even more precision. Both center pivot and drip irrigation can achieve efficiencies of up to 95%.

Industry accounts for 22% of global water consumption, and solutions to improve water use within industrial processes have led to significant industrial efficiency gains in recent years. For example, systems that provide real-time monitoring and control of chemicals used in boilers and cooling water applications have proven extremely effective in helping industrial firms reclaim and reuse billions of gallons of water in recent years.

Personal water demand, representing 8% of global consumption, can also be reduced through efficiency measures. While using water saving appliances and fixtures, such as low-flow showerheads or front loading washing machines can definitely cut down on a home's water use, the residential water distribution system itself can also be improved. The World Bank estimates that each day, enough water to supply nearly 200 million people is lost through leakage, costing utilities more than $14 billion annually.[24] Innovative companies have begun to provide advanced solutions to monitor and inspect pipelines, using sound waves and other technologies to detect leaks and assess pipeline conditions, allowing water utilities to prioritize maintenance and fix breaks in aging systems before they happen. And when repairs are needed, cured-in-place pipe products allow utilities to repair and rehabilitate water pipes while they are still in the ground.

Land degradation has taken its toll on crop yields in recent years

Food Scarcity

"Around the turn of 2011-12 the global population is forecast to rise to 7 billion, stirring Malthusian fears. Price rises have once again plunged into poverty millions of people who spend more than half their income on food. The numbers of those below the poverty level of $1.25 a day, which had been falling consistently in the 1990s, rose sharply in 2007-08. That seems to suggest that the world cannot even feed its current population, let alone the 9 billion expected by 2050."

THE ECONOMIST, FEBRUARY 2011[25]

"It's salty and it has butter and you don't know you're eating dirt. It makes your stomach quiet down."

OLWICH LOUIS JEUNE, 24-YEAR-OLD HAITIAN RESIDENT[26]
Quoted in *The New York Times*, speaking of the growing market in Haiti for consumable patties made of oil, sugar, and mud

AFTER A BRIEF REPRIEVE DURING THE RECENT GLOBAL RECESSION, FOOD PRICES ROSE RAPIDLY THROUGHOUT 2010, TO REGAIN THEIR PREVIOUS RECORD HIGH LEVELS REACHED IN THE CRISIS OF 2007-2008. IF THESE FOOD PRICE LEVELS ARE IN FACT A "NEW NORMAL," THAT "NEW NORMAL" IS UNSUSTAINABLY HIGH.

FOR VULNERABLE POPULATIONS, RECENT PRICE INFLATION THREATENS HUNDREDS OF MILLIONS OF PEOPLE WHO LIVE AT THE MARGIN OF DAILY SURVIVAL, AND ARE NOW IN DANGER OF FALLING BELOW THAT MARGIN. AND IT IS FAIRLY WELL ESTABLISHED THAT UNTENABLE FOOD PRICES WERE AMONG THE MAJOR CATALYSTS FOR THE UPRISINGS IN EGYPT AND TUNISIA, AS WELL AS ONGOING UNREST ACROSS THE MIDDLE EAST AND NORTH AFRICA. HOWEVER, FOOD SHORTAGES AND CONSEQUENTLY HIGHER FOOD PRICES ARE NOT JUST ENDEMIC TO THE MIDDLE EAST. THROUGHOUT THE DEVELOPING WORLD, THERE IS NOT ENOUGH FOOD TO SUPPORT SURGING POPULATIONS. IN MARCH 2011, THE WORLD BANK'S FOOD PRICE INDEX WAS 36% ABOVE ITS LEVEL A YEAR EARLIER; KEY STAPLES HAD EXPERIENCED PRICE SPIKES FROM A YEAR EARLIER, INCLUDING CORN (+74%), WHEAT (+69%), SOYBEANS (+36%) AND SUGAR (+21%).[27]

THERE ARE A VARIETY OF INTERTWINED DRIVERS OF FOOD SCARCITY. AMONG THE MOST SIGNIFICANT:

1) Emerging market demand

In our oil and water discussions we covered the rapid growth in global population and the rise of a new middle class within emerging markets. According to Goldman Sachs and Brookings, as many as 2 billion people will join the middle class over the next 20 years,[28] and among their many new consumer demands they will want a transformed diet – more food per capita per day, and significantly more meat per capita per day. Largely based on this trend, world meat consumption is expected to double by 2050 as reported in *The New York Times*,[29] and the impact on agricultural capacity will be tremendous, since it requires approximately 3-5 pounds of grain feed to produce one pound of meat, in addition to the 1,800 gallons of water mentioned above. Already, the stress is being felt in agricultural areas in China, which is preparing to import significant grain to feed its people for the first time in modern history.

Further aggravating the issue in China (and other countries) is its loss of farmland to urban sprawl. In 1996, China had approximately 130.07 million hectares of farmland; by 2008, that figure had dropped to 121.8 million hectares – a loss of 6.4 percent of its arable land in 11 years, mainly to urbanization.[30]

These demographic factors combine to form a grim picture of the future – huge increases in agricultural demand, accompanied by the sacrificing of farmland to accommodate the very population that is demanding more food. All in countries which are struggling to even meet the current demands of their populations.

2) "Food for fuel" policies in the United States

Driven by economic subsidies designed to support U.S. farmers and ease dependence on foreign oil, the market for ethanol in the U.S. has exploded in the past decade, with U.S. production increasing more than fivefold during that period to more than 12 billion gallons in 2010. This has resulted in more crops being diverted to fuel, with almost 40% of the U.S. corn crop for the 2011 season expected to become ethanol. The U.S. is itself responsible for close to 40% of world ethanol production and 60% of exports; as more and more corn is diverted to produce ethanol, it has a significant impact on global corn inventories and prices. Global corn inventories are expected to drop for a third consecutive season this year; before the next harvest, inventories will be equal to 15 percent of demand, the smallest since 1974, according to USDA data.[31] And the increasing competition for corn supplies between food, livestock and fuel demands is largely responsible for the significant increase in global corn prices over the past year according to the World Bank.[32]

Biofuels Digest reports that if current laws stay in place, U.S. fuel refiners will be required to blend 36 billion gallons of biofuel annually into auto fuel by 2022, up from 12 billion in 2010.[33] The current USDA roadmap to achieve this goal includes 15 billion gallons of ethanol (requiring close to 60% of our corn crop at current production levels). That roadmap also includes a 20 billion gallon production target for advanced biofuel such as cellulosic ethanol; given that these technologies have yet to be commercialized (the USDA expects 2011 production of cellulosic fuel to be less than 7 million gallons[34]), the demand for corn for ethanol may be even greater.

Demand for corn for fuel has a ripple effect on other crops as well. The price differential between crops is one of the key considerations for farmers as they make planting decisions. When corn is selling at a premium due to mandated ethanol demand, farmers naturally plant more corn, and that means lower volumes and higher prices for other crops.

3) Obstacles to crop yield growth

Perhaps our biggest ally in keeping pace with food demand growth over the past century has been our ability to consistently increase crop yield productivity. However, the growth rate in crop yields has slowed considerably in recent years. From a robust 3.5% growth rate in the early 1970s, crop yields are growing at only 1.25% today, according to the UN Food & Agriculture Organization.[35] That's barely enough to keep up with global population growth.

There are some systemic obstacles to increasing crop yield growth, such as widespread land degradation, as well as the diminishing returns of increased fertilizer use – as noted recently by Jeremy Grantham, fertilizer use has already increased five-fold on a per acre basis in the last 50 years[36] – but as we've been reminded recently, nothing controls the fate of a growing season like the weather. Throughout the world, calamitous weather events in recent years decimated crops. These included the worst drought in 130 years in 2010 in Russia and the Black Sea region, lasting long enough to damage winter planting as well as the summer harvest. As a result, Russia imposed an export ban on grains, creating shortages and driving prices higher. This was compounded by late rains in Canada, La Niña disruptions in Argentina, and an epic drought in five wheat-growing provinces in northern China. In Sri Lanka, food shortages were clearly linked to an unnaturally long and harsh monsoon season, with much of the country's rice crop lost to flooding.

Increased variability in weather patterns is considered a likely impact of climate change; although it is not possible to label any of the above events as a direct result of climate change, the trend is a disturbing one and has certainly driven food scarcity in the near term. Should climate conditions worsen, potential outcomes might include even more frequent weather anomalies, as well as the specter of consistently reduced crop yields – in Lester Brown's latest book, he notes that the rule of thumb emerging among crop ecologists is that every 1-degree Celsius rise in average temperature above the norm lowers wheat, rice, and corn yields by 10 percent.[37]

Supply-Based Solutions

To truly address our long-term global food scarcity issues, society will need to entirely transform its systems for food production and consumption. The International Water Management Institute's 2007 publication "Water for Food, Water for Life" provides just one of several excellent comprehensive assessments of how to transform global agriculture to meet the long-term needs of humanity (www.iwmi.cgiar.org/assessment/).

In the meantime, there are a number of interim solutions that can improve output. Some solutions offer potential benefits but

Please see FOOD SCARCITY page 10

Vegetables can be a rich source of protein otherwise found in meat

Up to 40% of food in the United States is wasted, according to NIH researchers

FOOD SCARCITY continued from page 9

also present consequences that many consider unacceptable; these include genetic modification of crops and / or livestock, and further expansion of factory livestock techniques.

A widening range of advanced equipment allows for more efficient and effective earth-moving, plowing, seeding, tillage, application of fertilizers, and harvesting. As mentioned earlier, improved irrigation can have a significant impact on crop yields. Newer automated technologies relying on GPS technology as well as sophisticated sensors can literally scan plants and soil while in motion, determine the immediate needs for fertilizer and other nutrients, and deploy those resources in exact amounts in real time.

Hybridization and genetic modification of seeds, although controversial, have led to dramatic improvements in crop yields. Certified seed, for example, can be customized to address special growing conditions and stressors in specific areas. So, for example, Ghana has excellent growing conditions for corn, but could produce far more with specialized seeds tailored to its specific requirements.

Demand-Based Solutions

As is the case with water, there are few solutions to reducing absolute food demand on a per capita basis. People need to eat. However, there are several drivers of inefficiency that can be addressed going forward:

- **Alternative protein sources** As noted several times in this discussion, the exponential growth in global livestock consumption is a chief driver of food scarcity. As such, any solutions that offer vegetable protein alternatives for human consumption are highly desirable. One simple option – that of using soy protein as a substitute for meat or as an "extender" in meat products – has been in use for many years. Soy protein used in the human diet has real benefits in terms of greater food efficiency per capita as well as lower fat and cholesterol, but also comes with real health risks in the form of high estrogen content, as well as a high incidence of soy allergies. More recently, technological advances have allowed economical extraction of food-quality protein from canola seeds for the first time; canola protein offers a stronger nutritional profile than soy. These new techniques may soon allow for protein extraction from other plants as well.
- **Food waste** People in the U.S. and other wealthy countries throw out a lot of food; and even if our collective conscience kicked in about that behavior, there would still be plenty of waste occurring before any food reached our plates. According to the USDA, just over 25% of our food in America goes into the trash,[38] and a 2009 study funded by the National Institutes of Health estimated that when waste along the full supply chain is included, "the amount of food lost all along the supply chain, including damaged produce from supermarkets, losses at processing plants, uneaten restaurant entrees, food that goes bad during transportation," the food waste figure for the U.S. is closer to 40%. As another example of how interrelated our scarcity issues are, the same study estimated that food waste was responsible for more than one-quarter of our fresh-water consumption and for approximately 300 million barrels of oil per year.[39]

While there is no silver bullet solution to address the food waste problem, investors can and should be aware of the "breakage" factor for companies within the food supply chain – restaurants, retailers, processors, farmers, and shippers. As food prices climb ever higher, the amount of product lost to waste within any company's operations will have a rapidly growing impact on its bottom line. □

Conclusion

The recent global recession was caused by a massive debt crisis; people borrowed far too much, conventional wisdom suggested the good times could last forever, but eventually there was no more easy money and the system imploded. Is our current situation regarding resource scarcity all that different? We've had an incredible 200 year run during this hydrocarbon era, with exponential growth in productivity and wealth. But from the factors we've discussed – and this short paper is certainly not a comprehensive catalog of evidence – it is impossible to come away without a sense that time is running out and our day of reckoning is fast approaching, if it has not already arrived.

On the topic of scarcity, Jeremy Grantham recently noted that "no compound growth is sustainable. If we maintain our desperate focus on growth, we will run out of everything and crash. We must substitute qualitative growth for quantitative growth."[40] We entirely agree; although we often use the term "sustainable growth" rather than "qualitative growth," the sentiment is the same. Throughout our discussion, we have referenced a number of resource scarcity solutions, some that improve supply productivity, others that reduce demand through efficiency or substitutes. Each of these represents a potential investment opportunity, and investors would be wise to pay attention to the companies that are rising to the scarcity challenge.

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EDITOR-IN-CHIEF
Jackson W. Robinson

MANAGING EDITOR
Ethan Berkwits

CONTRIBUTORS
Elizabeth Levy
Ellen Pfeifer

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