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Nuclear Energy at a Crossroads: Report from the World Federation of Scientists International Seminars on Planetary **Emergencies by Carmine Difiglio**

The World Federation of Scientists held its 50th Session of its International Seminars on Planetary Emergencies (the Erice Seminars). Over the years, the Erice Seminars have discussed many varieties of planetary emergencies. During the Cold War, its primary focus was avoiding nuclear conflict by bringing together influential scientists from the Soviet sphere, Western block and non-aligned countries.¹ Since then, Professor Antonino Zichichi, Chairman of the World Federation of Scientists and founder of the Erice meetings, has also focused the Seminars on everyday problems that cause human suffering with the aim that scientific understanding and consequent action can solve them. To achieve this goal, the Erice meetings bring together a wide variety of scientists, policy analysts and government officials to have multi-disciplinary discussions concerning severe threats to humanity as well as urgent everyday problems.

One of the urgent everyday problems is meeting the growing world-wide demand for electricity dramatically lower greenhouse with gas emissions. Achieving a sustainable world-wide power sector will require an ever-increasing share of electricity generating technologies that have extremely low greenhouse gas emissions such as renewable energy, nuclear power or the use of fossil fuels with CO₂ capture and storage.



Figure 1. Professor Difiglio listens to a question at the World Federation of Scientists International Seminars on Planetary Emergencies.

Only one of these options is showing healthy growth: wind and solar electricity, albeit growing from a small initial base. Nonetheless, we must ask, is it realistic to expect to decarbonize the power sector with only renewable electricity? Will nuclear power or fossil fuels with CO2 capture and storage also be needed?

This question received considerable attention at the 50th Erice Seminars as well as the future of nuclear energy in the world's power sector. It was noted that several recent nuclear projects in Western Europe and the United States have experienced long delays and large cost escalations. After spending \$9 billion, Santee Cooper and South Carolina Gas & Electric

¹ Including Edward Teller from the United States and Evgeny Velikhov from the Soviet Union.



announced that they were abandoning the construction of two nuclear power plants in the United States. Nearby, the Georgia Vogtle plant under construction is now estimated to cost \$25 billion compared to the estimated \$14 billion when construction began in 2012. It is by no means certain that the Vogtle reactors will be completed and, if they are, the final cost will be *at least* \$25 billion, perhaps significantly more.² Similar problems can be cited for reactor projects in Europe.

Recent experience building the current generation of nuclear reactors (Gen III+ designs), with enhanced safety features and modern control systems, has not been uniformly The poor performance of projects negative. involving the Westinghouse-Toshiba and Areva designs was not experienced in Korea while building reactors of their own design (OPR-1000, APR-1400), although the operation of their latest APR-1400 reactor was postponed to conduct more seismic studies.³ Rosatom was successful building the first VVR-1200 at Novovoronezh, a contemporary design with significant safety features.

Even with proven Gen III+ reactor designs, there are significant economic obstacles that nuclear power must overcome. High upfront investment is needed with lengthy and uncertain on-site construction that may be delayed by technical and other problems. These delays cause financing costs to escalate and public confidence in the project to erode. When completed, the plant's full power operation, day and night, means that its power is dispatched during many hours when it is not needed. Depending on the structure of the power market, a substantial share of nuclear power is sold at very low prices. In addition, the alternative lowemission power technologies, solar and wind, are becoming more competitive and typically enjoy public subsidies or minimum portfolio requirements. In the United States, due to fracking, natural gas prices are very low and, with a more competitive international gas market, even European and Asian gas prices may make natural-gas fired electricity cheaper than from new nuclear power plants.

The 50th Erice Seminars featured several expert presentations on nuclear power. Some of these discussed ways to make nuclear power much more attractive to investors and even safer than current Gen III+ designs. Smaller modular nuclear reactors could be manufactured and shipped to the nuclear plant complex. Steam would be provided from what are essentially turn-key reactors to the plant's steam-electric The time between financial generators. investment and power production would be vastly reduced. The reactors, being smaller, could be cooled with natural convection. They would also be much more resistant to earthquakes. Some designs would have much more infrequent refueling or never be refueled avoiding the weapons proliferation thus concerns resulting from refueling conventional reactors every 18 months and removing spent fuel rods.

It is an unanswered question whether companies will be able to produce and license these reactors at a competitive cost. The initial reason small reactors were not pursued decades ago was the belief that large reactors enjoyed large economies of scale and could produce electricity at a lower cost per kWh. Today, many large reactor projects appear to have significant diseconomies of scale because of on-site construction. Perhaps, with advanced manufacturing technologies, modular reactors could be produced at a lower cost per kWh than large reactors. No one knows for sure but several companies are constructing modular reactors for near-term deployment. We could soon learn whether the small modular reactor could change nuclear's role in a clean energy future.



² U.S. taxpayers would pay \$8.3 billion as a result of a DOE loan guarantee if the project fails.

³ Despite ROK's relative success in building Gen III+ reactors, the President of the Republic of Korea has announced a phase out of

nuclear power, citing the Fukushima reactors' melt down. Nuclear power currently provides about one-third of South Korea's electricity.

Natural Gas & LNG (see Technical Appendix for more data)

Prices for Japanese LNG spot cargoes hit a fivemonth high in August. The average contract price for spot LNG was \$5.80 per million British thermal units (mBtu) which was in line with the wider Asian benchmark. There was a slight recovery in prices in recent months in most regions, which may continue as colder temperatures increase demand for gas.

China's gas imports soared this year due to low import prices and government policies that have encouraged fuel switching from coal to natural gas. The January to August data show that LNG imports were up 26% from the same period last year.

In August, Russian natural gas exports to Europe via Ukraine reached their highest monthly level since December 2013, as volumes transiting Russia's western neighbor broke above 5 bcm for the first time in 3.5 years.

U.S. LNG exports resumed on September 6, following a two-week disruption due to the hurricanes in the U.S. Gulf Coast region. Meanwhile, Lithuania purchased a cargo of LNG from the United States, despite price competitive options from Russia.

India has agreed to buy extra LNG from Australia's Gorgon project in exchange for cheaper rates on its original supply contract. Petronet will take about another 1 million tons of LNG at 12.5% of the Brent oil price, while the original supplies will shift from 14.5% to 13.9%. Petronet had similarly reworked a long-term gas purchase deal with Qatar in November 2015 after spot rates crashed.

Oil Market

(see Technical Appendix for more data)

The Brent oil price has increased steadily since June. OPEC statements that the producer group will continue its quotas for the foreseeable future and a U.S. hurricane supported prices. The Brent-WTI spread in September has averaged \$5.53/b, up significantly from August's \$3.81/b and July's \$2.41/b. The drastic jump is the result of hurricane Harvey, which disrupted the supply of crude and refined products to U.S. and export markets.

This month, WTI was trading in a contango of about 44 cents per barrel between November 2017 and December 2017 compared with a backwardation of 22 cents in Brent. (In other words, WTI prices are expected to increase by December while Brent prices are expected to decrease.) These patterns are consistent with a tightening global oil market (Brent) and a local oversupply of U.S. crude as a result of refinery shutdowns and the closure of export terminals. Even though U.S. crude production was briefly impacted by Hurricane Harvey, its impact on Gulf Coast refineries and export terminals was longer lasting.

OECD industry stocks fell in June by 19.3 mb, and preliminary data for July showed further declines due to strong refinery runs and oil product exports, but are still 219 mb above the five-year average. The IEA meanwhile, expects a further drawdown of excess stocks as they are predicting higher 2017 growth in oil demand (raised to 1.6 mb/d growth over 2016; the IEA also recorded a 2.3 mb/d demand jump from the 2nd quarter of 2016 to the 2nd quarter of 2017).

OPEC crude output in August fell by 79 kb/d, the first monthly reduction since March. Total output for the group was 32.76 mb/d, which equated to 90% compliance with its supply target.

Renewables

China: Early in 2017, China announced that it would invest \$360 billion in renewable energy by 2020 while abandoning plans to build 85 new coal-fired power plants.ⁱ Already, China is investing more than \$100 billion in domestic renewable energy each year—more than double the investment of the United States and EU combined. Recently it was announced that China achieved its 2020 solar target of 105 gigawatts (GW) three years ahead of schedule after installed capacity reached 112 GW.ⁱⁱ



Global: According to a recent study by the consultancy Ernst & Young, global power and utilities deals in the second quarter of 2017 included \$6.1 billion in renewables.ⁱⁱⁱ According the study, to there have been limited for conventional opportunities generation investment in developed markets. while renewable energy opportunities have grown. The Asia-Pacific region accounted for more than half of the global deals.

United States: Residential small-scale (less than 1 megawatt) solar photovoltaic electricity generation continues to set monthly highs since 2015.iv The June 2017 estimate hit a monthly record high of 1,460 GWh, a 34.4% increase year-over-year. PV cost reductions, state policies, federal incentives and emerging market arrangements that facilitate net metering are driving the growth of small scale PV.

Economics

Turkey: Turkey's economy grew by 5.1% in the second quarter of 2017, more than double first quarter performance.^v This means that Turkey is one of the fastest growing economies. Household consumption, estimated to comprise nearly two-thirds of the economy, grew 3.2% from last year. Exports grew 10.5% while gross capital formation grew 9.5% from last year. Outlays on construction increased 25% while spending on machinery fell. Manufacturing growth, however, was up by 6.3%. Government spending on goods and services slowed at the fastest pace in more than two years, which, given this growth report, is a good sign for the Turkish economy.

Asia: Japan's actual economic growth in the second guarter was much slower than previously expected, according to recent government data.^{vi} Japan's economy expanded at an annualized rate of 2.5% in April-June, much less than an initial estimate of 4.0% growth. While the data weaken confidence in the may economic policies. other government's

economic indicators, such as a robust global demand and a tightening job market, are likely to sustain a steady recovery. In China, the economy showed further signs of slowing down in the second half of 2017, due in part to extended policies that impact property, borrowing, and industrial capacity.^{vii} Meanwhile, export growth slowed against economies in the U.S., Europe, and Japan, though accelerated in most Asian economies.^{viii} The export slowdown reflects the renminbi's recent appreciation against the U.S. dollar.

United States: The U.S. economy grew in the second quarter by 3%, the fastest rate in two years.^{ix} This is more than double the first quarter and better than initial estimates for the quarter. The economic momentum was driven by higher consumer spending and healthier business investment. The unemployment rate is expected to hold near 4.3%, a 16-year low.

The Fed remains puzzled about how to handle record low unemployment since U.S. inflation remains below the Fed's target rate of 2% (U.S. inflation appears to have stabilized at around 1.5%). This is yet another nail in the coffin of the Phillips Curve that postulates an inverse relationship between unemployment and inflation.⁴

The United States recently experienced severe hurricanes in the south, causing close to \$200 billion in damage.^x Long-term impacts are likely to be muted by increased output during the poststorm recovery and reconstitution.

Europe: Economic activity in the Eurozone increased faster than previously estimated in the second quarter, expanding 2.3% year-on-year against previous estimates of 2.2% growth.^{xi} GDP grew 2.4% on average across the EU, with the Czech Republic expanding fastest (2.5%) and Portugal and the UK the slowest. Britain's economy continues to grow by around 0.3% each quarter with multiple sectors, including the services sector, continue to underperform



⁴ Less pleasant evidence that the Phillips Curve had problems was the U.S. "stagflation" of the 1970s when unemployment *and* interest rates were high.

previous years.^{xii} Looking forward, the German economy is set to grow by more than 2% this year, which would be the strongest rate in six years, according to the Germany industry association BDI.^{xiii} Record-high employment, rising real wages, and ultra-low borrowing costs are driving a consumer-led growth.

Geopolitics & Supply

OPEC: Crude output in August fell by 79 kb/d, the first monthly reduction since March.^{xiv} Total output was 32.76 mb/d, which equated to 90% compliance with the target. Rising production in Libya and Nigeria has made it harder for OPEC to reduce its total output, as the two countries remain exempt from the group's current 1.2 mb/d reduction quota.

Iran: August's production rose by 100 kb/d to 3.79 mb/d compared to July.^{xv} The increase was in part due to increased demand for Iranian crude in Europe by 2.5% after output fell in Iraq and Saudi Arabia. Iranian crude supplies increased in Italy, France, the Netherlands, and Greece. Meanwhile, Iran's oil minister said this week that the Islamic Republic has considered supporting an extension of the supplier production quota.^{xv}

Iraq: Southern crude production in August fell slightly to 3.22 mb/d.^{xvii} Iraqi's parliament also rejected the northern government's referendum on Kurdish independence.^{xviii}

Libya: After increasing to over 1 mb/d in July, production fell by 130 kb/d in August due to the

forced closing of three oil fields and an attack on a primary oil export pipeline.^{xix} According to local officials, the three oil fields resumed production as of the first week of September. Libya has remained exempt from the OPEC cuts and will continue to be exempt through March 2018.

Nigeria: Output was nearly 1.9 mb/d in August from a low of 1.4 mb/d this year.^{xx} Nigeria is also exempt from the OPEC coordinated production quotas, which has dulled the impacts of OPEC's coordinated cuts. While there has been suggestion that OPEC will soon require Nigeria to cap its output, Nigeria's oil minister has stated publicly that he would not consider a quota until at least March 2018.

Qatar: While the economic blockade imposed by Saudi Arabia, the UAE and Egypt continues, Qatar has sustained exports of oil and LNG.^{xxi} Qatar is also trading other goods through swaps via Oman. Qatar is the world's largest exporter of LNG and OPEC's second biggest producer of condensates and NGLs after Saudi Arabia.

Saudi Arabia: Crude output was roughly 10 mb/d in August. Saudi production is expected to fall by 350 kb/d in October, in line with the Kingdom's average commitment to the OPEC-led supply pact (around 480 kb/d).^{xxii} Saudi output was trending higher in recent months. The kingdom cut production deeply early in the year, which compensated for other OPEC members that were not hitting their quotas.



IICEC Energy Market Newsletter Technical Appendix

1. Natural Gas & LNG

Prices:

- Prices for LNG spot cargoes for Japan, the world's top buyer, hit a five-month high in August.^{xxiii} The average contract price was \$5.80 per mBtu. This is in line with the wider Asian benchmark for last month, supported by sputtering output and stockpiling ahead of winter. Spot gas prices in Asia LNG had risen to \$6.05 per mBtu by the end of August from \$5.90 per mBtu earlier in the month. Across the board, there has been a slight recovery in prices, which may continue as colder temperatures tend to increase natural gas demand in most regions of the world. Strong demand was reported from China, Taiwan and South Korea, as buyers stock up ahead of the winter.^{xxiv}
- LNG demand has been firm, with Chinese LNG imports higher on the back of rising domestic sales thanks to increased switching from coal to gas by utilities.^{xxv} China's gas imports have soared this year. The January to August data shows that Chinese natural gas imports were up 26% from the same period last year. The strength of China's LNG appetite this year will depend on how low winter temperatures go, as well as whether there will be policy adjustments for the gas industry, which may be announced during the 19th National Congress of the Communist Party of China meeting in October. North Asia LNG buyers are also actively filling their LNG inventories in an attempt to manage the traditional winter peak Asian demand months.
- Weekly U.S. natural gas spot prices increased \$0.07 to \$2.93/mBtu on September 6, as temperatures fell across nearly every region of the United States.



Figure 1. Select Natural Gas Prices (mBtu)

Supply:

• High LNG output relative to demand is likely to weaken, as LNG demand is expected to double by 2035.^{xxvi} While production plants in operation or under construction will add to the global supply, aging facilities and shrinking resources in key



regions will lead to a tighter market. According to Cedigaz, global LNG capacity is expected to peak at 387 million tons a year by 2021-2022, while demand for LNG in China, India, Bangladesh, Indonesia, the Philippines, and Vietnam is expected to continue to grow beyond that time frame.

- In August, Russian natural gas exports to Europe via Ukraine to Europe reached their highest monthly level since December 2013, as volumes transiting Russia's western neighbor broke above 5 bcm for the first time in 3.5 years.^{xxvii} Total supplies via the Velke Kapusany interconnection point on the Ukraine-Slovakia border totaled 5.1 bcm last month, an average of 165 mcm/d, as maintenance constrained flows through the Yamal-Europe pipeline via Belarus and European demand for Russian gas in general remained strong. Meanwhile, Lithuania purchased a cargo of LNG from the United States, despite price competitive options from Russia.
- India has agreed to buy extra LNG from Australia's Gorgon project in exchange for cheaper rates on its original supply contract.^{xxviii} Petronet will take about another million tonne of LNG at 12.5% of the Brent oil price, while the original supplies will shift from 14.5% to 13.9%. Petronet LNG, a state-owned gas importer originally signed a deal with Exxon Mobil in 2009 to purchase 1.44 million tons of LNG annually for 20 years, and began receiving supplies in January at a rate that was much higher than the spot. Petronet had similarly reworked a long-term gas purchase deal with Qatar in November 2015 after spot rates crashed, leaving the company with fewer consumers willing to accept.
- U.S. LNG exports resumed last week, following a two-week disruption due to the hurricanes in the U.S. Gulf Coast region.^{xxix} LNG vessel loadings resumed at Sabine Pass liquefaction terminal on Wednesday, September 6 with the arrival of LNG tanker Rioja Knutsen (LNG-carrying capacity 3.8 bcf). The port of Sabine Pass was inaccessible to LNG vessels for almost two weeks, as port operations were suspended in the wake of Hurricane Harvey. The last loading at Sabine Pass liquefaction facility prior to the hurricane was on August 24. Currently, six vessels are around the Sabine Pass port waiting for a loading window, according to Bloomberg. The Sabine Pass terminal has two loading berths, allowing two LNG vessels to load at the same time.

2. Oil Market

Oil Supply and Prices:

- The Brent oil price has increased steadily since June's \$47.58/b, with prices averaging \$49.06 in July, \$51.87 in August, and \$53.68 so far in September. Geopolitical risks from North Korea, expectations that OPEC will continue its quotas for the foreseeable future, and a U.S. hurricane supported prices.
- Between August 25 and September 10, two catastrophic hurricanes made landfall in the southern United States. Hurricane Irma, the second of the two, has caused significant damage and some fatalities in Florida. However, Florida is a consumer, not a producer of crude, petroleum products and natural gas. In contrast Hurricane Harvey made landfall in the Gulf Coast of the United States with its offshore oil platforms, onshore oil production, half of U.S. refinery capacity, half of U.S. working crude oil storage capacity, and 40% of working storage for both gasoline and diesel fuel.



• The Brent-WTI spread in September has averaged \$5.53/b, up significantly from August \$3.81/b and July's \$2.41/b. The drastic jump is the result of hurricane Harvey and Irma, which disrupted U.S. refinery runs and U.S. Gulf Coast economies and thus demand for U.S. crude oil. Also U.S. crude exports and imports were impacted by the massive storms and resulting damage to petroleum infrastructure.



Figure 2. Benchmark Crude Prices

- The price of WTI fell significantly, with front-month prices trading at a discount to Brent of around \$5.30/b compared with \$2.75/b on August 14. WTI is trading in a contango of about 44 cents per barrel between November 2017 and December 2017 compared with a backwardation of 22 cents in Brent. Backwardation in Brent is consistent with a tightening global oil market while contango in WTI is consistent with local oversupply of crude as a result of refinery shutdowns and the closure of export terminals. Since most of the price effects are consistent with previous storms, and no catastrophic damage has been reported in the U.S. oil sector, there should be no long-term impacts to price forecasts or investor behavior.
- U.S. weekly crude production has grown steadily throughout the year. Weekly production peaked recently at 9.53 mb/d during the week of August 25, though experienced an 8% drop the following week due to Hurricane Harvey. Production has since recovered to pre-storm levels with output averaging 9.35 mb/d last week, according to US EIA. U.S. oil production began to grow in the 4Q16 after declining over the first three quarters of last year. Average production for 2016 (8.9 mb/d) was below 2015 (9.4 mb/d), though still 1.3 mb/d higher than the average for 2011-2015.

Crude Storage:

- OECD industry stocks fell in June by 19.3 mb, and preliminary data for July show further declines due to strong refinery runs and oil product exports, but are still 219 mb above the five-year average. According to IEA, in 2Q17, global oil stocks drew by 0.5 mb/d, including 0.2 mb/d in the OECD. Refining throughput is expected to reach its annual peak in August, with runs at 81.4 mb/d. 3Q17 throughput is forecast to grow 0.9 mb/d year-on-year.
- U.S. commercial crude inventories increased by 5.9 mb during the week ending September 8.^{xxx} At 468.2 mb, U.S. crude oil inventories are in the upper half of the range for this time of year, based on the five-year average. Crude imports averaged



6.5 mb/d, down by 603 kb/d from the previous week, due to the Hurricane. U.S. crude exports increased by 591 kb/d from the previous week to 774 kb/d. Weekly exports reached an all-time high of 1.30 mb/d in late May.





Select Product Markets:

• According to IEA data, year-on-year global total oil demand growth remained strong in 2Q17, at 1.8 mb/d (1.9%). Some regional markets have flipped into backwardation, showing that the process of destocking has started in parts of the global oil market. Oil products, rather than crude, have led the charge (Figure 4).



Figure 4. Select Monthly Product Prices in Europe, Japan, and North America

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⁵⁻Aug 5-Sep 5-Oct 5-Nov 5-Dec 5-Jan 5-Feb5-Mar 5-Apr 5-May 5-Jun 5-Jul 5-Aug

• **Gasoline prices in Turkey** are shown in Figure 5, with prices increasingly steadily since July, driven by increased Brent oil prices.





- For the week ending September 8, U.S. crude oil refinery inputs averaged 14.1 mb/d, down 394 kb/d from last week. Gasoline production fell as a result of Hurricane Harvey, while refineries operated at 77.7% of their operable capacity. For the week ending September 1, gross inputs to refineries in the U.S. Gulf Coast fell by 3.2 million b/d, or 34%, from the previous week.^{xxxi}
- U.S. gasoline stocks increased by 1.6 mb, and they remain in the upper limit of the five-year average for this time of year. The national average retail regular gasoline price increased to \$2.685 per gallon on September 11, \$0.006 higher than last week and \$0.403 higher than a year ago.



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Figure 6. Weekly U.S. Gasoline Stocks and % Change





For any questions and additional information, please contact:

Prof. Dr. Carmine Difiglio E: <u>carminedifiglio@sabanciuniv.edu</u> P: +90 (212) 292 49 39 / 1111 Dr. Mehmet Doğan Üçok

E: mdoganucok@sabanciuniv.edu

P: +90 (212) 292 49 39 / 1112





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