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CENTER FOR RENEWABLE ENERGY EDUCATION AND DEMONSTRATION (CREED) PROJECT

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POSITION PAPER NO. 1

A MANIFESTO FOR PAUSE

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INTRODUCTORY NOTE:

At their July 26, 1999 meeting, CREED's Board unanimously expressed their desire to see this position paper placed into the hands of Energy, Environmental and Economic (3E) decision makers at the earliest opportunity. They did so however with the proviso, that recipients set aside time to be alone for careful reflective thought before attempting to read it. So until you have time set aside to digest it, please STOP HERE!

1. A MANIFESTO FOR PAUSE:

The Random House Dictionary (1, p. 1169) defines "manifesto" as "a public declaration of intentions, opinions, objectives, or motives, as one issued by a government, sovereign, or organization". In this case it is a public declaration of my organization, Center for Renewable Energy Education and Demonstration (CREED) Project. *Random House* (1, p. 1423) has several definitions for "pause". The sense intended here is best given by definitions 2 and 7; def. 2. "a cessation of activity because of doubt or uncertainty", and def. 7. give pause "to cause to hesitate or be unsure, as from surprise or doubt".

2. BACKGROUND:

Industrialized nations and the U.S. in particular have set themselves up for increasingly unstable situations both environmentally and economically in the next couple of decades. In fact by the year 2010 either or perhaps even both of these systems may have experienced disruptions of such major consequence that the world as we know it today in 1999, may never again be the same. To say this may label me as a doomsday prophet, but I base my judgment on the evolution of facts and data that are currently being produced and disseminated by the scientific and economic communities.

In the industrialized world, transportation for the most part is tied to the petroleum fueled internal combustion engine. Gasoline, diesel and aviation fuel power over 95% of all transportation prime movers, on land, water and in the air. Our whole way of life is inexorably linked to the supply of cheap oil, and this applies regardless of whether we are talking about the industrial/commercial sector's transportation needs, or the general public's love affair with the private automobile - or should I now say SUV? Even for those of us who would like to move to a different transportation fuel, the options are few or non-existent because the culture in which we find ourselves forces us into its mold.

3. FLUID FLOW AND TURBULENCE:

Recently I have become intrigued by what the physical phenomenon of "turbulence" might tell us about what to expect in the environmental and economic systems of our planet. The study of fluid

dynamics with which engineers and physicists will be familiar tells us that turbulence is a manifestation of instabil-ity in the flow of a fluid. Fluid flow is either steady state or lamina, or if the conditions dictate unstable or turbulent. Engineers use dimensional analysis to come up with a dimensionless number or figure of merit in fluid flow to tell them whether a particular fluid flow will be lamina or turbulent. This number is known as the Reynolds Number, R, after Osborne Reynolds (1842-1912) an Irish engineer and physicist (2). This number is used to express the relation between the velocity, viscosity, density, and a characteristic length dimension of a fluid in any system of flow. R is used in aerodynamics to correct the results of tests of scale model airplanes in wind tunnels, by hydraulic engineers in the design of dam spillways, channels and penstocks and generally to predict the behavior of the flow - whether it will be laminar or turbulent.

The Reynolds Number is dimensionless since it is the ratio of two forces acting on the fluid. In the numerator is the inertial force that drives the flow and tends to make it turbulent, and in the denominator the viscous force which tends to impede its flow and keep it lamina.

i.e. $R = F_{inertial}/F_{viscous}$

R is generally reduced to the form: -

$$R = (lv\rho)/\nu$$

where l is the characteristic length, e.g. the diameter or radius of a pipe.
v is the mean velocity of the flow.
ρ is the density of the fluid.
and ν is the viscosity of the fluid.

Generally when R exceeds a value of about 5,000 to 10,000 the flow will degenerate from steady state or lamina to unstable or turbulent.

Now what has the Reynolds Number to do with the environment or the economy? Well, in engineering and science we always look for analogies from one study or topic for applications in the analysis of other subjects. For example, analysis of the phenomenon of resonance, which has been highly developed by electrical engineers to explain the behavior of tuned circuits in communications theory, is directly applicable to mechanical and acoustical systems where resonance also takes place. An understanding of the factors and parameters involved enables the engineer to either maximize the resonance effect or damp it out if the resonance could prove to be destructive. I decided to start looking at what the Reynolds Number might tell me about the two Es of Environment and Economy.

4. TURBULENCE IN ENVIRONMENTAL SYSTEMS:

Climatologists have been telling us that there is a link between global warming and the increased incidence of severe and destruc-tive weather occurrences. The linkage goes like this; - increased burning of fossil fuels has pumped greater and greater amounts of CO_2 into the earth's atmosphere so that the proportion of CO_2 has increased from about 290 to 360 ppm over the last century (3, fig. 3.2, p. 25.). CO_2 is a green-house gas - i.e. it is trans-parent to the sun's shortwave radiation, but tends to be opaque to the much longer wavelength infrared (IR) radiation which the earth emits back towards space. So thermal (heat) energy is trapped and the earth's average global temperature increases. But what is not generally known is that only about 30% of this trapped energy goes into the sensible heat associated with this temperature rise. The rest - 70% of the trapped energy goes into latent heat, i.e. the evaporation of water, principally from the planet's tropical oceans. Thus the amount of water vapor passing through the earth's atmosphere has been steadily increasing during the last 100 years and especially in the last ten.

Climatologists to a person tell us that it is the water vapor in the atmosphere that gives rise to increased atmospheric instability. I decided to find out how an increase in humidity affected the Reynolds Number for atmospheric fluid flows and particularly if it had any bearing on the Jet Stream. To find out I visited Prof. Ken Davis of the University of Minnesota's Department of Soil, Water and Climate on the Saint Paul Campus. Prof. Davis' area of research actually involves tracking down unaccounted for discrepancies in the CO_2 balance between fossil fuel burning, natural decay processes, ocean absorption and sequestering, and land biomass (esp. forests) sequestering. First, I was informed that the Reynolds Number was not a good indicator of atmospheric turbulence because R already is so large that only air flows with characteristic lengths of one inch or less could truly be regarded as lamina, e.g. the lamina boundary layer associated with the airflow over an aerofoil.

Furthermore what gives rise to truly turbulent unstable conditions in weather are not the horizontal flows of air but the vertical up and down drafts associated with large temperature differences, and how these are created. Davis suggested that another dimensionless number, the Richardson Number, which has vertical temperature difference as its driving factor, is a much better determinant of this vertical weather activity.

Qualitatively, the thinking goes like this. Global warming is increasing the quantity of water vapor passing through the atmosphere. As landmasses heat up during sunlight hours, the heated air above them begins to rise. Cooler air from the oceans, carried horizontally by the jet stream and pulled in convectively, is increasingly moist and this moisture gets sucked up as air continues to rise from the land based heating. When this air reaches higher altitudes the water vapor begins to condense forming clouds, rain droplets and ultimately the hailstones whose continued upwards movement generates the electrical charge separation of thunderstorms. Since condensation and freezing are exothermic processes, the released latent heat warms the air reinforcing the updraft which carries the droplets and stones to higher and higher altitudes. Finally the droplets and stones become so heavy that they begin to fall. Reaching drier mid altitudes some of them begin to evaporate and sublimate back to water vapor again. These are the reverse processes of condensation and freezing, so are endothermic and extract latent heat from the air, cooling it. Now the cooled air begins to sink causing a downdraft. If sufficiently intense the downdraft becomes a downburst. When this rapidly sinking air reaches the ground it has no choice but to spread outwards (4). These downburst generated straight-line winds can exceed 100 mph and are capable of causing widespread damage as happened recently in the Boundary Waters Canoe Area (BWCA) of Minnesota.

The other destructive forms of weather-generated turbulence in the atmosphere are the tornado over land, and the hurricane or typhoon over oceans and their associated coastal areas. The incidence of these has increased in both frequency and intensity (3, pp. 3-4 and table 1.2) in the last couple of decades and computer modeling by climatologists suggests that these events will continue to increase in frequency and severity. A good example of the latter was the legion of twisters that ripped through Oklahoma and Kansas on the afternoon and evening of Monday, May 3, 1999 (5). Weather forecasters categorize tornadoes on the Fujitu (F) Scale with F0 (40-72 mph winds) being the least and F5 (261-318 mph) the most severe. Starting at 5:00 pm and continuing for 20 hours, more than 40 twisters scourged the region. One, an F5 behemoth originating near Chickasha, on the ground for four hours, ripped an 80 mile strip of complete destruction Northeast through a corner of Oklahoma City and several of its suburbs. This tornado was historic, not for the width of its funnel - although at nearly a mile across, that was extraordinary - but in that a mobile Doppler radar from the University of Oklahoma clocked its peak wind speed at 318 mph. This is the strongest wind that has ever been recorded on earth! Storms of this magnitude beg the question - What is the greatest intensity possible? Could we ever get an F6? Well the Chickasha Twister was awfully close. Rod Sterling in his Sci-Fi novel *Heavy Weather* (6) sets up the plot and necessary climatic ingredients for just such an event. We hope such an event never occurs but after OK99 we are now not so sure.

Nobody likes turbulence and instability, at least not of the sort that we are beginning to see in our climate in recent years, and least of all the insurance companies who have taken a terrible beating recently. Maybe there is a touch of irony in the chain of events associated with our use of fossil fuels. No one disputes the fact that first coal and now cheap oil has brought labor saving devices, comfort and ease of trans-portation to our lives and in so doing these fuels have reduced the turbulence, stresses and instability of life from a practical point of view. But at what cost in terms of global warming? The jury is still out; ten years from now we will probably know the verdict.

5. TURBULENCE IN ECONOMIC SYSTEMS:

Since the CREED Project has as its mission 3E Education and the final E is Economy, we are naturally also interested to find out whether fluid flow theory can be applied to economics. Again I sought out the help of an expert in the field, this time Prof. Alfred Marcus, Director, Strategic Management Research Center of the Carlson School of Management at the University of Minnesota. His area of research is Energy Policy and he has studied this with respect to the development of nuclear and renewable energy sources as well as fossil fuels. These are summarized in his book *Controversial Issues in Energy Policy* (7). In particular I wanted his help in determining whether a Reynolds Number analogy could be applied to economic systems as a predictor of instability or turbulence in them. Even though our discussion did not move beyond more than a qualitative assessment of such an analogy, what we did discover was I believe extremely important and intriguing and definitely worthy of research to move it from the merely qualitative to the quantitative.

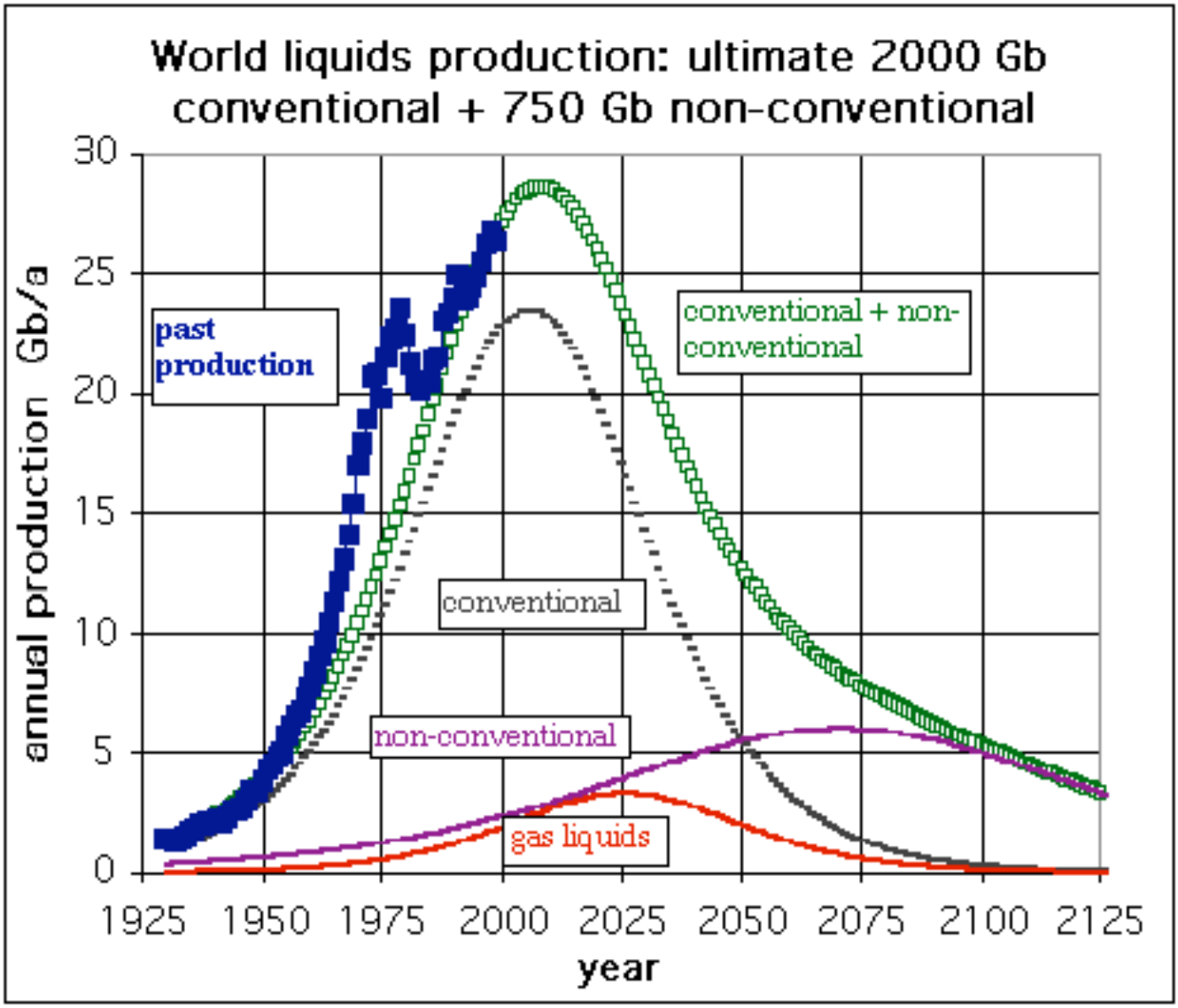
Recall again that the Reynolds Number expression is: - $R = (lv\rho)/\nu$.
We began with a discussion of the factors in the numerator. In economic terms "l" would be associated with the volume of flow, "v" with the rate of flow and ρ with the unit cost of goods, services and capital in a free market system. Since the driving force in such a market system is the profit motive, business executives attempt to increase all three of these factors. I asked Marcus, specifically with respect to the velocity factor, "v", "Does increasing "v" increase the potential for economic instability?" With hardly a moment's reflection he replied, "Undoubtedly, and what you have to remember is that the profit motive is in turn fueled by greed". This was the first of a couple of quite surprising statements that he would make during our interview that would in turn inspire my own inductive reasoning. Looking at these factors in the numerator more carefully; first, if "l" is associated with the volume of flow, then R is proportional not to volume, "V", directly but to the cube root of volume (i.e. $R \propto \sqrt[3]{(V)}$). This means that instability as measured by R is much less sensitive to volume of economic flow than it is to either rate of flow, "v", or unit cost, "ρ". Unit cost of course is constrained by what the market will bear unless of course it is contrived by connivance and price fixing, which leaves "v" as the factor most susceptible to "greed manipulation".

Next we turned to a consideration of the denominator, viz. the viscosity factor, "ν". What are the determinants that tend to impede or slow down the flow of goods, services and capital in an economic system making it more stable? I assumed that government action; through regulations and taxes would be the major determinants; e.g. Anti-trust legislation, OSHA safety regulations in the work place, workman's compensation, corporate taxes and the like. Marcus agreed, but then he took time out to consider the significance of the "ν" factor further. Finally he offered, what was for me his second rather surprising statement. "You know", he said, "In a capitalist, free market system like we have here in the United States, a stable economy would be impossible without justice". What did he mean by that? I believe what he meant was that without men and women of integrity in business and government who place doing the right thing in terms of their relationships with other people above the profit motive, a stable economic environment would rapidly break down into turbulence, instability and chaos, by virtue of greed, graft and corruption. I came away from this interview a little shaken and very much subdued as a result of these revelations, but nevertheless very thankful that our current apparently stable and prosperous economy in the United States exists because we still have a sufficient number of men and women of integrity in positions of economic decision making. Compare our economy with that which exists currently in some other countries, e.g. Russia.

There is a further question we must ask. Are there possible events, perturbations or pressures that could cause our economy to become unstable and throw our whole culture and way of life into chaos? Just as a smoothly flowing stream suddenly breaks into uncontrolled turbulence as it cascades over a waterfall, is there an event or events that could do the same to our economy? I believe there is and it could occur within the next decade, i.e. by 2010 unless we take steps to do something about it.

6. THE END OF CHEAP OIL?

The March 1998 issue of *Scientific American* includes a special report entitled, "The End of Cheap Oil: It's Coming Fast. But New Technologies Might Prevent an Energy Crisis". In the first article (8) of this report, petroleum geologists, Colin J. Campbell and Jean H. Laherrère postulate that global production of conventional oil will begin to decline sooner than most people think, probably within 10 years. This postulate is based on analytical techniques first developed by M. King Hubbert, a geologist with Shell Oil, in the mid fifties. In 1956 he predicted that oil from the lower 48 states would peak around the year 1969 (9). Production actually peaked in 1970, and even with addition of oil from Alaska's North Slope, total U.S. produced crude has been declining ever since. This shortfall in U.S. consumption needs has been made up by exports from Canada, Mexico, Venezuela and of course the Middle East. Some people believed that the oil crises of 1973 and 1977 represented a peaking of oil production globally in the sense that conventional oil was becoming more difficult to extract even in the Middle East. However, this was not so. What had happened was that the five Middle Eastern members of the Organization of Petroleum Exporting Countries (OPEC) - Saudi Arabia, Iran, Iraq, Kuwait and the United Arab Emirates) had managed to capture 36% of the global market and were able to connive to hike prices in concert. After this, demand fell by virtue of conservation efforts, and fresh Alaskan and North Sea oil weakened OPEC's economic stranglehold with the result that prices also fell.



This graph is based on an Ultimate Recovery of liquids (conventional oil plus natural gas liquids) of 2000 Gb and Non-Conventional oil of 750 Gb. [from Dr. Jean Laherrère, 2000]

The next oil crisis will not be so temporary. Campbell and Laherrère's analysis of the discovery and production of oil globally suggests that within a decade, i.e. by the year 2010, the supply of conventional oil will be unable to keep pace with demand. From an economic perspective, when the world runs completely out of oil is not directly relevant. What matters is when production reaches its peak and thereafter begins to taper off. As Campbell and Laherrère state, "Beyond that point, prices will rise unless demand declines commensurately". The switch from growth to decline in oil production will thus almost certainly create economic and political tension.

To be fair not all geologists and authors agree with Campbell and Laherrère. Curtis Rist in a recent article, "Why We'll Never Run Out of Oil" (10), takes Campbell to task for his gloomy predictions, on the basis that he discounts the ability of technology to fill the gap by producing oil from natural gas, oil shale, tar sands and even coal, all of which have potential re-serves far in excess of that of crude oil. True, the potential energy reserves in these sources could supply the world's oil needs for many decades if not centuries to come, but what Rist fails to emphasize strongly enough is that oil produced from these other sources will come with a hefty price tag. First we have the costs of the technology itself which will almost certain-ly double the price of gasoline at the pump. Secondly and more seriously, although he does admit this, are the increasing emissions of greenhouse gases, despite the Kyoto Protocol's agreement by the United States and 37 other industrialized nations to reduce them to a level 5% below 1990 levels by 2012.
(Ed. Note: The Bush Administration withdrew America from this agreement in 2001).

At least, increased prices for oil will spur the production of alternatives, e.g. ethanol and other biomass produced fuels, along with electric vehicles using improved batteries and fuel cells, but can the required changes be made in 10 short years? With the world currently swimming in cheap oil and short-term greed abetting this situation, few companies and governments are bothering to spend much on alternative fuel and prime mover technologies except where required to do so by environmental concerns (e.g. California). In addition cheap oil fuels a denial complex on the part of the public that a problem really exists. Add to that the situation that our world and culture is wired for oil with hundreds of thousands of gas stations around the globe, and the truly intractable nature of the issue becomes apparent. 10 years is too short a time span for an orderly transition to trans-portation alternatives to be carried out without a major dislocation in the economies of industrialized nations and particularly in that of the U.S. viz.-a-viz. Japan and Europe since our gasoline taxes are so low.

The potential for economic instability in the U.S. in the next 10 years is thus very real. When prices begin to rise, the general public will look for scapegoats and vested interest groups will demand special treatment and tax relief from their governments. Will we still have a sufficient number of men and women of integrity in decision-making roles to place doing what is right above the temptation to capitulate to bribery and greed? Our whole free market system will be in jeopardy. Will it survive?

7. A CALL TO SINGLE-MINDEDNESS:

In the introduction to the second edition of "Global Warming: The Complete Briefing" (3), John Houghton states - "In the first edition I included a chapter, chapter 8, with the heading 'Why Should we be Concerned?' which addresses the question of responsibility of humans for the Earth and for looking after the environment. In it I presented something of the basis for my personal motivation as a Christian for being concerned with environmental problems." He then goes on to state that since this was something of a departure for a scientific text, he wondered how it would be received. He was pleased with a generally favorable response from colleagues and reviewers to the inclusion of ethical and religious issues. On reading chapter 8, I found myself, also as a Christian, resonating strongly with the views he expressed. Furthermore, I believe that the responsibility that God has given us to be **good stewards** of His physical creation, i.e. of the environment, should be extended also to economics. When the Bible tells us that "The love of money is a root of all kinds of evil" (11), and "Keep your lives free from the love of money and be content with what you have" (12), it lays down a cardinal ethical principal for us all. Note that **it does not say** that money is in and of itself evil, money in its various forms, tangible and intangible is needed as the means of currency for economic transactions. What **it does say** is that it is the **love** of money (i.e. greed) that is a precursor of evil and as a consequence an affront to our relationship not only with God but also with the people around us.

When the patriarch Jacob gathered his sons around him on his deathbed, of his firstborn, Reuben, he said, "Turbulent as the waters, you will no longer excel" (13). Reuben was characterized as

turbulent because he was basically an unstable man trying to move in more than one direction at the same time. Turbulence of character also manifests itself in ambivalence, impulsiveness, indecision and doubt. For those of us who struggle with these deficiencies, the Bible again offers strong counsel. It states clearly and incisively - "If any of you lacks wisdom, he should ask God, who gives generously to all without finding fault, and it will be given to him. But when he asks, he must believe and not doubt, because he who doubts is like a wave of the sea, blown and tossed by the wind. That man should not think that he will receive anything from the Lord; he is a doubleminded man, unstable in all he does" (14).

My concern for 3E Education, is thus motivated and driven by the Judeo-Christian ethic of stewardship for our Environment and our Economy and I consider myself blessed to be able to devote my time and energy to it and to be surrounded by men and women on my Board who share this view.

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