To Walter Youngquist<br>PO Box 5501<br>Eugene, Oregon 97405, USA

Dear Walter

Being lazy I rarely write letters, preferring to send e-mails.
But I cannot send you e-mails and you have sent me so many letters with interesting articles, cartoons and pictures of wild animals.
So I have decided to send you a letter.
First thanks for sending me the Population Reverence Bureau 2012 world population data sheet.
You are very concerned by the growth in population (1 000000 mouths every five days) and you are right, but the situation is more complex: half of the world population is below replacement rate of 2.1 child per woman and will be extinct in few generation, when presently one billion has a fertility range from 4 to over 7 and will survive from the data from World Bank. The present range of countries between 2.1 and 4 births per woman is likely to trend towards 2.1.
Figure 1: world fertility rate versus cumulative population in 2010 from World Bank


In 1950 no country has a fertility rate below 2.1 , when in 1995 there were 2.1 billion people and in 20103 billion people.

The most fertile countries (population over 10 M ) do not show strong decline for the last 10 years, except Afghanistan (because the war), even some increase like Zambia or Malawi. It will take a long time for these countries to reach below 3 births per woman.
Figure 2: change in fertility rate 2000-2010 for most fertile countries from the World Bank


Countries with more than 29 M and with present fertility rate between 2.2 and 4 have been declining since 1980 and likely with trend towards the replacement ratio of 2.1 , in contrary with the most fertile countries which shows little or no decline
Figure 3: change in fertility rate 1980-2010 for countries with population $>29 \mathrm{M}$ \& rate between 2.2 and 4 in 2010 from the World Bank


Most of population forecasts are based on scenarios on fertility rate, like the UN 2003 revision with forecasts up to 2300 where every countries is assumed to trend towards 2.1 to keep the world population steady. It is a wishful thinking scenario where in 2100 the most developed countries (in blue) have a higher fertility rate than the least developed countries (in green): quite unrealistic! But in the UN 1998 revision the target of 2.1 was the goal for every country in 2050!
Figure 4: UN 2003 medium forecasts for fertility rate


In their new revision in 2010 (forecast to 2100), the UN has increased the fertility rate. The sharp decline from 5 births in 1950 to the present 2.5 is hard to extrapolate.
Figure 5: UN world fertility rate from 2001 to 2010 revision as PRB, CIA \& WB past data


The best cause of change in fertility rate is education of young females and access to water and health.
The relationship between fertility rate and female literacy was shown in 2008 from Work Bank data
Figure 6: fertility rate versus female literacy in 2008 from World Bank


The new data in 2012 from World Bank shows a move towards better education and the relationship with high fertility is not as strong but it stays.
Figure 7: fertility rate versus female literacy in 2012 from World Bank


In 2004 I was forecasting the oil peak around 2015, the gas peak around 2030, the coal peak around 2035.
Figure 8: world coal, oil \& gas annual production 1850-2150 in 2004


The fossil fuel peak was then around 2025 and the population peak around 2050 from the Un (a little sooner from my modeling). The energy per capita (in green) was then flat from 1975 to 2025, meaning that the consumer will only see energy decline I after 2025 Figure 9: world fossil fuels annual consumption per capita 1850-2100 modeled in 2004


In 2003, the population peak was easy to model because the peak of annual growth in percentage was declining from 1970 to 2000 trending towards 2035 and 8.8 G Figure 10: world population annual growth in \% modeled in 2003


Figure 11: world population annual growth in \% versus population modeled in 2003


The trend looked clear in 2003, but now the data shows a complete different trend.
Reliable data on population are scarce: there are countries like Somalia, which has no census. Countries lie on population as they lie on oil reserves or oil production when there are quotas. In 1990 the UN estimated Nigeria at 120 M people but the census of 1991 showed that the real number was $30 \%$ lower.
The best population source on the web seems to be the World Bank, which compiles several sources, giving the historical data for each country. The plot from 1960 to 2010 of the world annual growth in percentage as in number (million) shows a different behavior. The sharp increase in 1962 was due to the China famine in 1960 and should be ignored.
The world annual growth in percentage (in blue) peaked in the 1960s around $2 \%$ and declined from 1970 to 2000 trending towards zero growth (population peak) in 2050, but since 2000 the decline has slowed by half and the linear trend is trending towards 2150.
The world annual growth in number (in red) peaked in 1990 and declined until 2000 trending towards 2100 , but since 2000 it grows, meaning no peak in the long-term!

Figure 12: world population annual growth in number \& in \% from WB in 2012


The same growth plotted versus the world population can be extrapolated giving the population at the peak. The growth in \% could be extrapolated before 2000 towards about 10 G , but after 2000 towards 18 G . The growth in number could be extrapolated before 2000 towards 14 G , but after 2000 there is growth with no peak in view.
Figure 12: world population annual growth in number $\&$ in $\%$ versus world population


USCB (http://www.census.gov/population/international/data/worldpop/table_population.php) displays the annual growth and for the period 2015-2050 they guess a decline going from 78 M to down 44 M : it is pure wishful thinking, not in line with the data of the last 12 years.
Figure 13: world population annual growth 1950-2050 from USCB 2012


Using different sources (USCB, WB, EIA, PRB) for annual growth in number, the data since 2000 is chaotic and roughly shows a constant growth around 77 M, when before EIA data for 1990-2000 trends towards a peak in 2040.
Figure 14: world population annual growth in million from different sources


It appears that past population growth could not be modeled reliably and that the forecast should come from the behavior from birth and death. In the past population growth was low because mortality was about the same as birth rate. The mortality rate (per 1000 people) (in red) has decreased from 1960 to now from 18 to 8 with the progress in health, when birth rate (in green) peaked in 1965 and declined from 34 to 20 because family planning changed sharply in educated countries with the pill, but since 2003 the decline is flattening.
Figure 15: world death and birth from WB 1960-2010


The difference between birth rate and death rate (in blue) is on decline but since 1987 it looks like an exponential decline, which will be in 2100 still above 2 and not zero to obtain a zero growth.

Hans Rosling in a very good video (http://www.ted.com/talks/hans_rosling_religions_and_babies.html ) connects fertility rates and incomes (income and education are also connected) for every country in the world, broken down into religions and circle represents population. He forecasts 10 billions in the long run.
http://video.ted.com/talk/podcast/2012S/None/HansRosling_2012S.mp4
Figure 16: births versus incomes by country in 2010 by Hans Rosling


The same plot for 1970 shows few countries below 2.1 babies per woman.
Figure 17: births versus incomes by country in 1970 by Hans Rosling


But human behavior is irrational (education is disturbed by religion or by myth) and modeling is very unreliable.
In Japan, an educated country, the number of births in 1966 dropped by 26\% (through abortions) as this year is assumed to be a malefic year (Hinoe-Uma = the Fire Horse, coming every 60 years) where the girls born this year cannot be a good wife (even can kill their husband). There was also in the previous cycle 1906 a drop of $7 \%$ (abortion was more difficult).
Figure 18: Japan live births and $1966=$ Hinoeuma


The most famous population forecasts are those from the UN, but their forecasts vary with the year of the revision from 1987 to 2010 (last one) up and down
Figure 19: world population forecasts from UN 1974 to 2010 for medium variant


The world fertility rate has vary from UN revisions 2000 to 2010 but the variation is small compared to the past decline
Figure 20: world fertility rate forecasts from UN 200 to 2010 for medium variant


The UN estimate for the world population in 2050 was above 11 G in 1974 to down to 9 G in 1998 and up to 9.3 in 2010. The estimate for fertility rate in 2050 was 2.15 births per woman in 2000 to down to 2.02 in 2008 and back to 2.17 in 2010.
Figure 21: world population and world fertility in 2050 from UN revisions 1974 to 2010


Past data on fertility rate are very questionable and forecasts are wishful political guesses (as told above) to get replacement ration for the world in the medium variant. Furthermore the low and high variants were chosen with a wide range since a long time, recognizing the difficulty to forecast!
Figure 22: world fertility rate for UN 2010 with low, medium and high variant


Population forecasts have increased largely from UN 1998 to UN 2010 for the world, Africa, but not for Europe.
Figure 23: population forecasts from UN 1998 \& 2010


From UN 2010, Africa population equals Europe population in 1995 and in 2050 will be three times larger (more than 5 times in 2100).
Europe being in the decline, the only solution for Africa will be to flood Europe!
Figure 24: Africa \& Europe population forecasts from UN 1998 \& 2010 and ratio


Present population forecast from UN sees no peak before 2100 when IIASA 2007 saw a peak around 2060.
Figure 25: world population forecasts from UN; USCB \& IIASA


The Population Reference Bureau publishes on the web since 2004 every year a "world population data sheet" providing data for each country as the forecast for 2025 and 2050 For the world their past data is linearly extrapolated and compared to their forecast for 2025 and 2050, as also the UN 2010 forecast.
It looks that the 2025 forecast at 8.1 G is close to PRB linear extrapolation and UN at 8. But for 2050 the present forecast is much less than the linear PRB extrapolation, but more than UN estimate. it means that world will grow less than linearly.
Figure 26: world population forecasts from PRB data 2004 to 2012 with forecast for 2025 \& 2050 evolution compared to UN 2010


The same plot for Europe shows that Europe will grow much less than linear extrapolation of past 9 years (low fertility rate)
Figure 27: Europe population forecasts from PRB data 2004 to 2012 with forecast for 2025 \& 2050 evolution compared to UN 2010


The same plot for Africa shows that Africa will grow more than linear extrapolation (high fertility rate)!
Figure 28: Africa population forecasts from PRB data 2004 to 2012 with forecast for 2025 \& 2050 evolution compared to UN 2010


Most of Africa population growth comes from Sub-Saharan Africa where fertility rates are high, as it is shown on figure 2.
Figure 29: Sub-Saharan Africa population forecasts from PRB data 2004 to 2012 with forecast for 2025 \& 2050 evolution compared to UN 2010


To conclude on population, UN forecasts are based on political wishes (world fertility rate trending to replacement ratio) and are unreliable and no one can model population with a good model. However UN 2010 population forecast, which is likely too high, is used to forecast energy consumption per capita. The USCB forecast to 2050 is also used.
-Energy consumption
Historical energy data are hard to find and they are questionable because the lack of consensus in energy equivalence, in particular for nuclear energy and renewable energy. In 2001, France has changed their energy equivalence in order to be in line with IEA conventions. In the change in the energy mix, the nuclear energy was increased from $31 \%$ to $39 \%$ and hydropower was reduced from $7 \%$ to $3 \%$ !
France primary energy for 2001 in Mtoe

> in \%

|  | new method | old | new method | old |
| :--- | :--- | :--- | :---: | :---: |
| coal | 11,98 | 11,9 | 4 | 5 |
| oil | 96,5 | 99 | 36 | 39 |
| gas | 37,2 | 37,2 | 14 | 14 |
| nuclear | 134,4 | 79,1 | 39 | 31 |
| hydro, wind \& sun | 6,8 | 17,7 | 3 | 7 |
| other renewable | 12,2 | 12,1 | 5 | 5 |
| total | 269 | 257,1 | 100 | 100 |

In my paper Laherrère J.H. 2011 «Saving energy: reliability of national energy flows» ASPO USA 2011 peak oil \& energy conference Nov 3-5 Washington long text http://aspofrance.viabloga.com/files/JL_ASPOUSA2011.pdf
I have shown the chaotic data of country energy flows from different agencies.
It is the same for primary energy consumption from different sources, for the past and for the future. The old data on biomass (wood and dongs!) vary widely. BP does not include wood in the primary energy because unreliable!
Figure 30: world primary energy consumption 1850-2035 from different sources


IEA/WEO 2011 (in green) forecasts a linear trend in primary energy, being the usual "business as usual", like OPEC/WOO 2011, but Exxon 2012 (in black) displays a flattening towards 2035. My guess is that primary energy will flatten towards an ultimate of 18 Gtoe because the limited amount of resources on earth, like Paul Valery wrote in 1931 "The time of limited world begins".
Figure 31: world energy primary consumption per capita 1850-2200 with population and primary energy


The data for fossil fuels production is slightly more reliable and can be modeled using the ultimates estimated from extrapolation of mean backdated discoveries, assuming that there will be no above ground constraint, which is unlikely because we are in a deep economic and financial crisis. The drastic increase in growth of coal production comes mainly from China
and China is now in a house bubble ( 65 millions empty houses, when only 3 millions in Spain). There is a wild uncertainty between coal ultimates between university writers (Rutledge, Patzek, Hook, Zittel) and agencies like BGR and WEC. Because my early forecasts were too pessimistic based on an ultimate of 600 Gtoe , my new coal estimate is 750 Gtoe (5.4 Tboe), giving a plateau 2040-2060. My ultimate is 3 Tb (plus asymptotic biofuels) for all liquids and 2.2 Tboe for natural gas, giving a fossil fuels ultimate of 10.6 Tboe. The FF peak is around 2025 at 12 Gtoe/a.
Figure 32: world fossil fuels annual production \& forecasts


This graph should be compared to my guess in 2004 figure 8
Using population past data and USCB \& UN forecasts, the fossil fuels production per capita is presently at peak around 12 boe/cap, being at 11 boe/cap in 2025 and at 8 boe/cap in 2050. The comparison with the primary energy production per capita modeled with an ultimate of 18 Gtoe shows that the nuclear and renewables, which add 1.4 boe in 2010 should be adding 2.8 boe in 2025, 6.3 boe in 2050 and 8 boe (being twice the fossil fuels) in 2100.

Figure 32: world fossil fuels annual production per capita compared to primary energy per capita for an ultimate of 18 Gtoe.


This graph should be compared to my guess in 2004 figure 9 , the new graph is more pessimistic because the change in population forecast.

I have also updated my forecast for gold and silver production, because my previous forecast was too low mainly by the uncertainty on China resources.
-gold production
My previous gold production forecast was modeled with an ultimate of 250 kt taken from USGS reserves estimate. But my forecast of a gold peak in 2000 at 2.6 kt was wrong, after a trough in 2008 at 2.4 kt , production in 2011 at 2.75 kt is on the increase pushed by a high gold price and new mines in China \& Mongolia.
Previously USGS was estimating the reserves, as the reserve base, but USGS has dropped this last estimate. The extrapolation of the change in cumulative production plus remaining reserves and the recent production data pushed me to try also a new ultimate of 310 kt , but keeping also one with 260 kt .
Figure 33: world gold cumulative production and reserves from USGS \& forecast with 260 \& 310 kt


Modeling past production with 8 cycles (Ho is the basic one with peak in 2020) and an ultimate of 310 kt forecasts the gold peak around 2015 at 2.8 kt with a sharp decline but a less steep decline after 2040. But there is the likely case of a new cycle with the discovery of new gold mines in poorly explored areas.
The other pessimistic ultimate at 260 kt provides a steep decline declining to a very low production in 2100.
Figure 34: world gold annual production and cycles modeling for an ultimate of 310 \& 260 kt

-silver

My previous silver ultimate was a round 2000 kt , but new data in particular from USGS leads to a more precise 2200 kt . The USGS cumulative production plus reserves is now over 2000 kt.
Figure 35: world silver cumulative production and reserves from USGS \& forecast with an ultimate of 2200 kt


The silver peak is forecasted to be around 2015 with 25 kt and the decline is steep, except if a new cycle (new large discovery) occurs.


If gold and silver productions reach peak this decade, the world will realize that we have reach the end of unlimited resources and that we have to change our way of life!

