Energy in Revolution

Exergy – ″Energy″ System is Arriving

I dont like such one environment. Do you like?

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Hon. Mb.: IIR, ASHRAE, REHVA, SITHOK, KGH, SLOSE

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SWWBG

Solar

Water

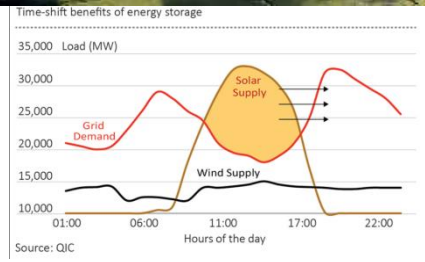
Wind

Biomass

Geothermal

Intermittency

Problem to by solved!



Setting the Scene: Stress-es on the World

1. Sociological: population growth, environmental problems, exploitation of natural resources;4 Megatrends

2. Economical: consumer society, inequity;

3. Technological: exergy destruction, chemical pollution, IKT, IoT, IIoT;

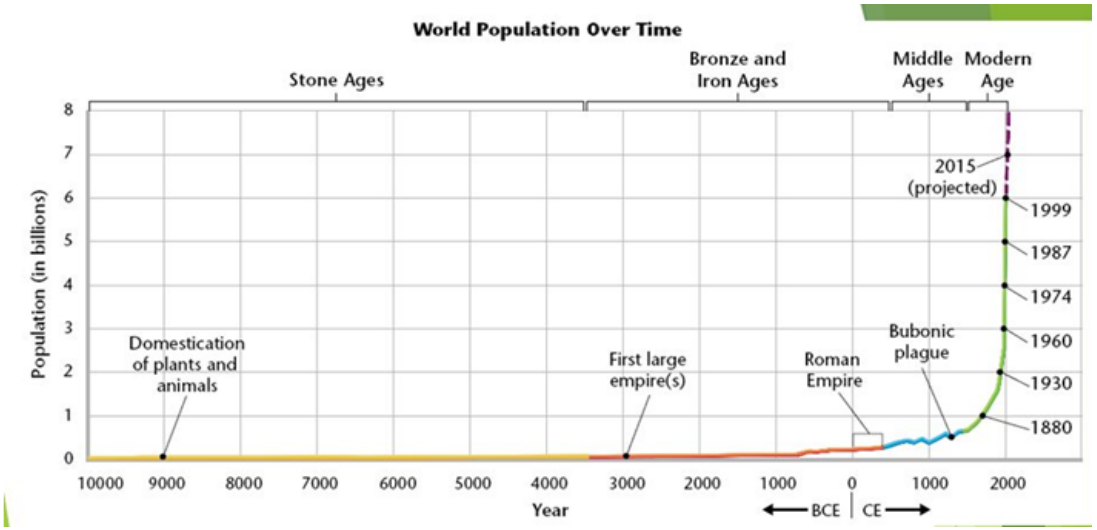
For HVAC we consume more than 40 % of fossil fuels.

1. Society: "Living well within the limits of the planet...."

4 Important Megatrends:

1. Population Growth

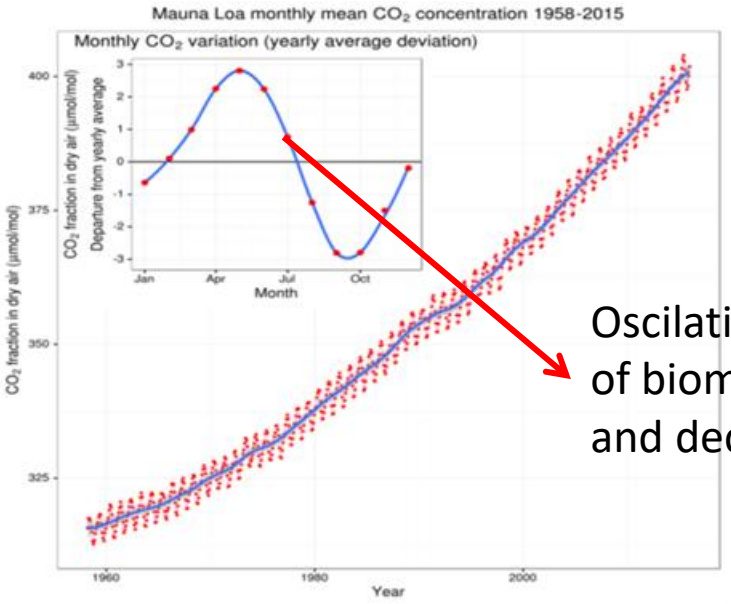
For a first billion we needed 12,000 years. At present we need only **14 years for a new billion**. Can we survive such exponential growth?



2. GHG Emissions

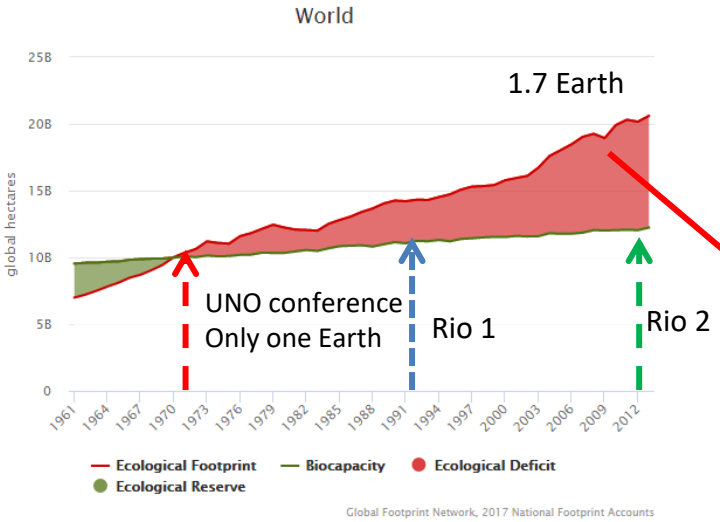
400 ppm of CO_2 was overridden in 2016. Temperature rise of 1,5 K is almost achieved!

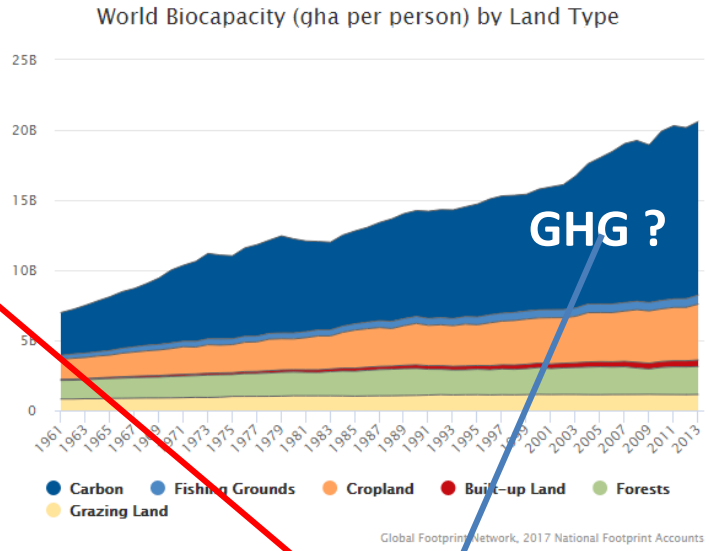
2 K goal from Paris agreement can be surpassed !?



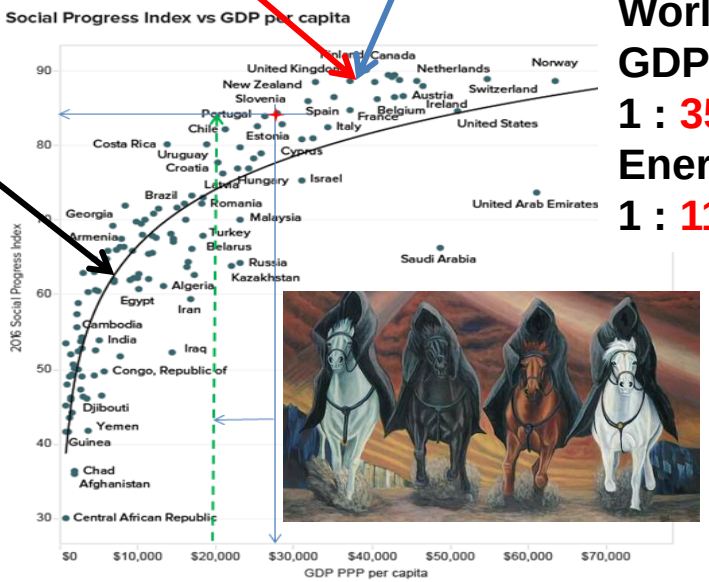
Oscilation because of biomass growth and decay - 6 ppm/y.

3. Ecological footprint





4. Uneven political, economic and social development on the World



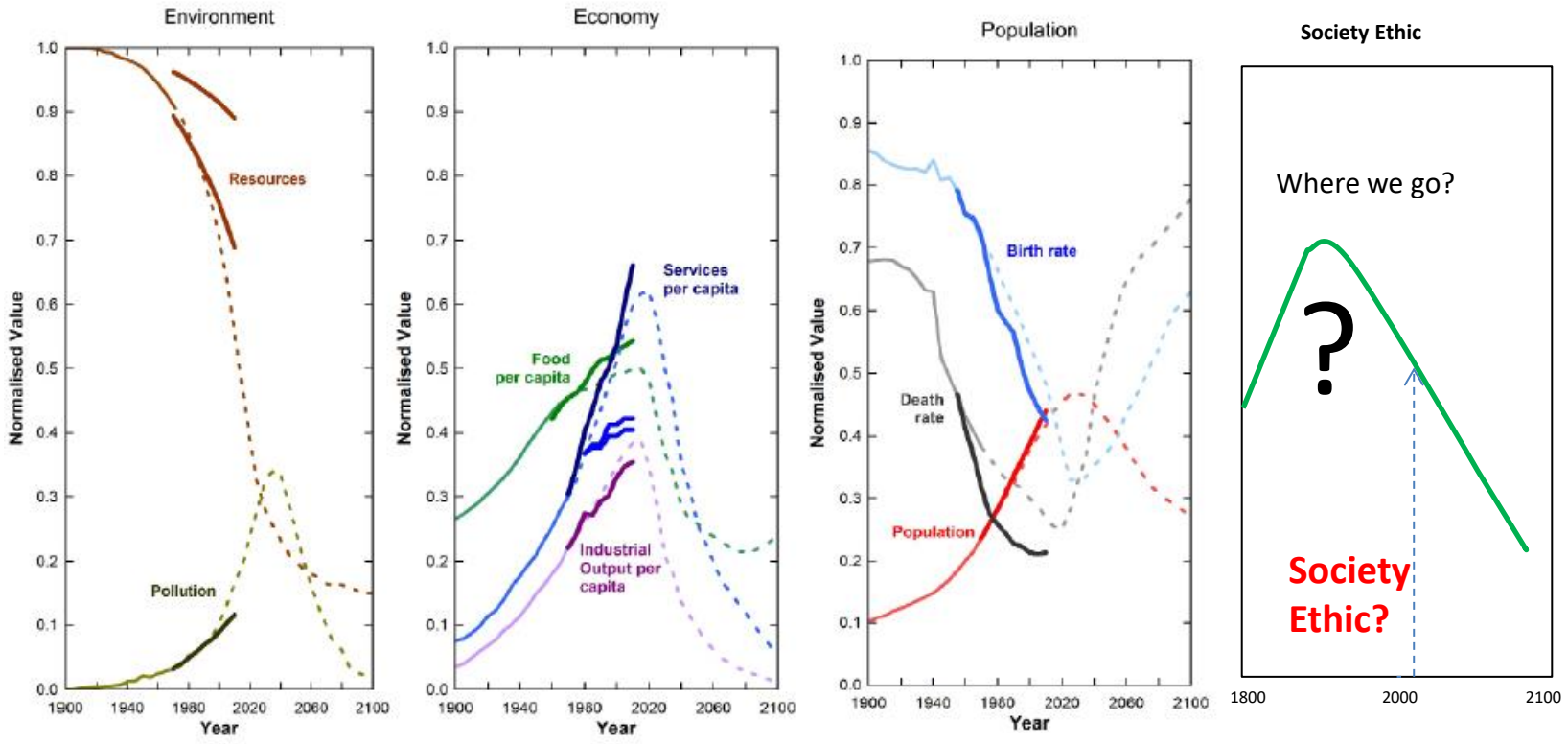
World:
GDP/cap
1 : 350
Energy/cap
1 : 115

Are this 4 megatrends four rider of apocalipse?

Death,
Famine,
War,
Conquest.

2. Economy: In 45 years we cannot change our development patterns!

In the Club of Rome book „Limit of the Growth“, 1972 we can find simulation model for world development „Business as usual“. Putting in the graph the real data of development on the world (UN Statistic) for last 45 years we find large agreement with prediction they made. Humanity is approaching the collapse in next decades if present development pattern will not be changed.



3. Technologies

Humanity has developed many different and for the environment unacceptable techologies, like:

- Fosil fuels transformation (power plants, engines,...)
- Agriculture machine (raising food production,...)
- Urbanisation
- Road transportation
- Air transportation
- Chemistry (fertilizer, plastics,....)
- Medicine (medicaments,.....
- Military equipment (wapons, explosives, nuclear technologies...)
- Land use and cities growth (fertil land thightening, forest reduction...)

Two important questions are obviuos:

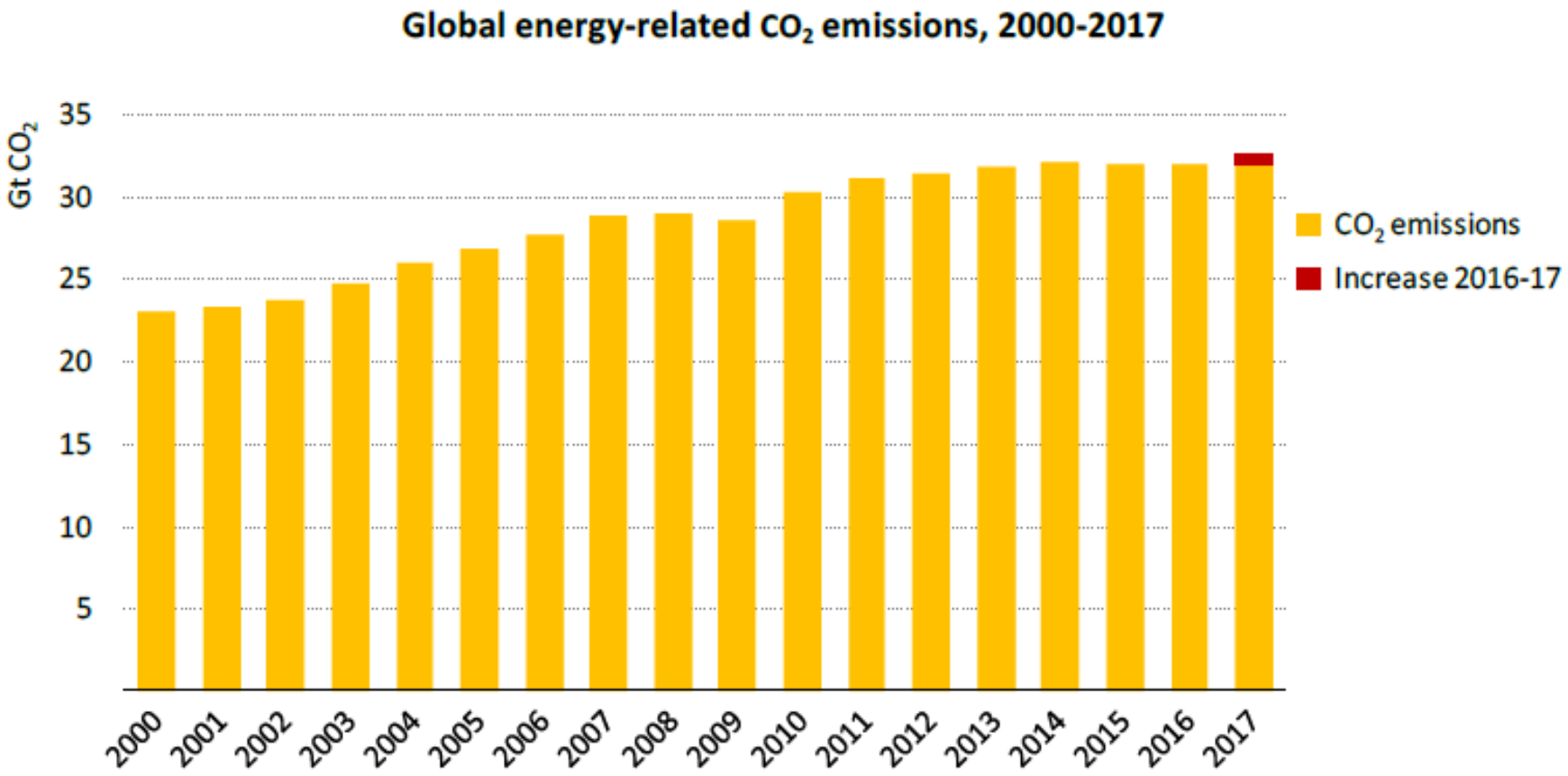
How to stop the environment degradation on the planet?

Where and how to start?

My answer is: starting with return to the sun!

Sun is begining and end of the life on the planet!

Latest Emission Data: IEA 2017 Report



Stress in Environment and RE ?

Do we like such one country wiev?

Can we do RE on different ways

STRES (with no stress)

- **S**USTAINABLE - environmental friendly
- **T**RANSACTIVE - inter communicative
- **R**ENEWABLE - using solar exergy
- **EXERGY** - energy part, able to do work
- **S**YSTEM - from producer ower transmitter, dealer to consumer

EXERGY VERSUS ENERGY

What is Exergy: part of Energy able to do Work

Energy = Exergy + Anergy

Anergy is Energy of Environment

Exergy is a measure for Energy quality!

We need exergy, anergy is available for free anytime, anywhere.

Solar energy is pure exergy!

STRES axioms:

- **General use of RE will be possible only, if we find the chemical storage of solar energy** (prof. dr. Tabor, 1975, Paris Conference on Renewable Energy).
- **Only natural chemical storage of solar exergy is biomass** (including plants and animals).
- **Integration** of the daily solar exergy with natural stored solar exergy – biomass, is the optimal solution.
- **IIoT and IoT** will enable us to overcome the daily and yearly oscilations of RE and to assure needed **exergy** flows in new system.

Resources evaluation, exergy efficiency,

- Resources cannot be evaluated only according to mass and energy balance, because they not disappear.

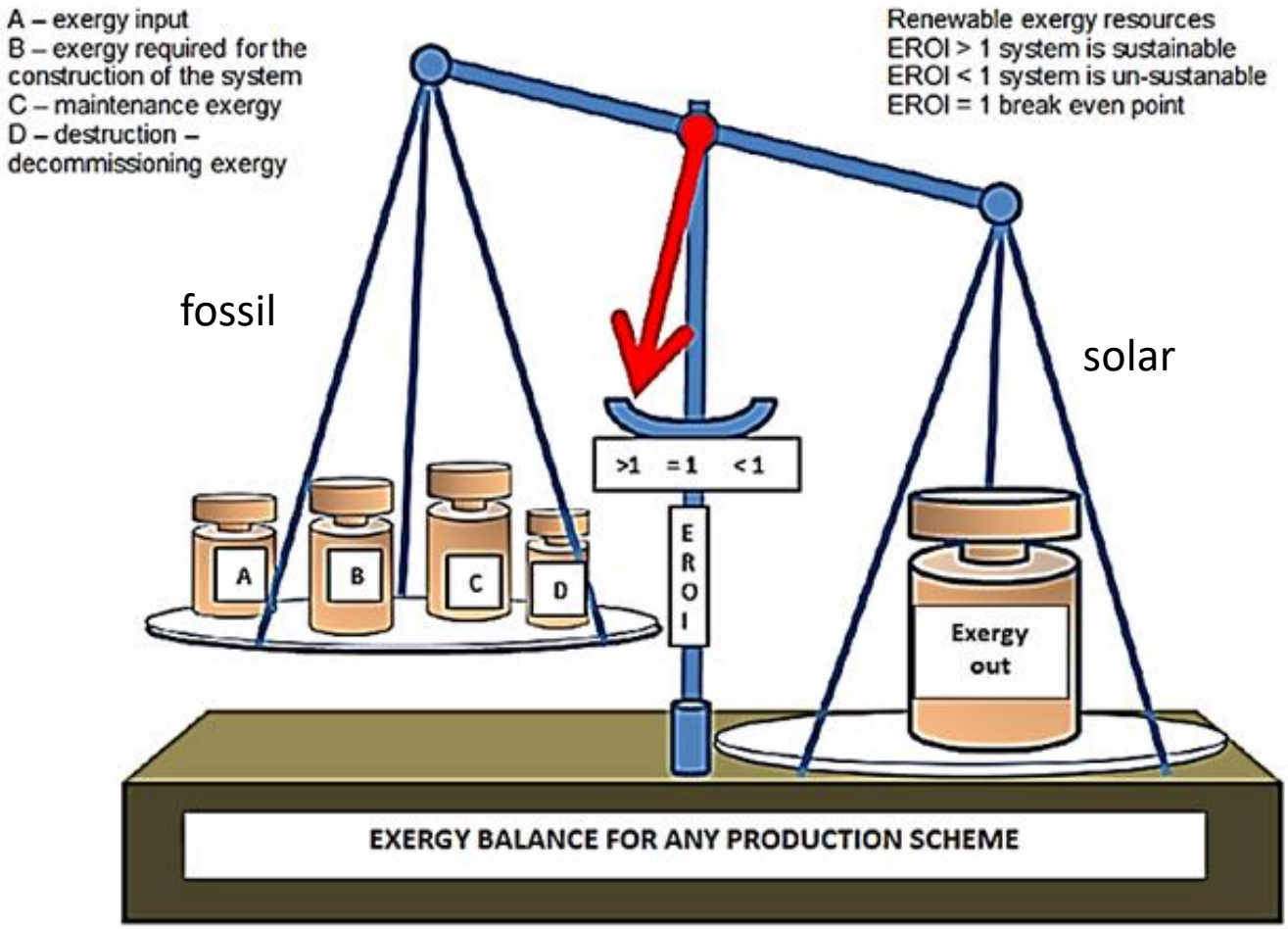
- Using the exergy as measure of resources depletion we can evaluate quality of our processes taking into account the conservation of mass, energy and irreversibility's - loss of exergy in our processes.

- Exergy Efficiency (EE) is a measure for quality of exergy transformation in processes - measure for irreversibilities.

Sustainable development and Circular economy - connection to exergy

- **Sustainable development** means les exergy destruction or depletion in all circumstances.
- **Circular economy** is a policy to minimize the use of resources, to minimize the thermodynamics irreversibility's, this mean to promote higher exergy efficiency over the life cycle
- **Indicators** for exergy in circular economy are:
  1. Life Cycle Exergy Analysis LCExA (Short LCEA)
  2. Exergy payback time ExPBT (EPBT)
  3. Exergy Return on Exergy Invested ExROExI (EROI).

Exergy balance for any production scheme



Source: Davidson, 2011

Requirement for STRES

To fulfil the daily exergy needs of different consumers, the new (energy) – exergy system has to response to the following six main requirements:

1. Source of exergy must be inexhaustible, available everywhere on the planet;
2. Zero emission of GHG using the new exergy carriers;
3. Available any place and any time (in all needed forms of exergy: solid, liquid, gaseous fuels and electricity).
4. Must be compatible with existing infrastructures with minor adaptations;
5. In transition period the present energy system and SES has to work in parallel with no interference (coexistence of two systems);
6. Should be competitive with fossil fuels system if all external environmental costs will be included in their exergy carriers' price.

Concept of Sustainable Transactive Renewable Exergy System

Sustainable transactive exergy system (STRES) as proposed*, consists of the four main renewable **exergy** (energy) carriers:**

1. Renewable electricity (surplus will be used for H_2O electrolysis),
2. Gas - methane CH_4 (from biomass and solar hydrogen),
3. Liquid - methanol CH_3OH (biomass + solar hydrogen and oxygen)
4. Solid fuels from biomass (for transition period, important in developing countries)

* Novak, 1990:The way to energy sustainable world, Elsevier, E&B,14, pgs. 249-256;
* Novak, 2015: Sustainable Energy System with Zero Emissions of GHG for Cities and Countries,
• E&B,http://dx.doi.org/10.1016/jenbuild.201410.085;
* Novak, 2017: Exergy as Measure of Sustainability of Energy System, Int. J. E/E Sci. 2017,2:139
** See: Ecofys: 2011, The Energy Report 100% Renewable Energy by 2050; www.ecofys.com .
Ecofys: 2018, Gas for Climate; www.ecofys.com .
Hydrogen Coucil: 2017, Hydrogen scaling up, www.hydrogencouncil.com.

Why methane and methanol?

The methane (CH_4) and methanol (CH_3OH) are the only exergy carriers in nature with one carbon chemically connected with four hydrogens.

In STRES both represent chemical storage of renewable exergy.

- Necessary hydrogen and oxygen will be produced with electrolysis of water or other processes, equalizing the renewable electricity daily and yearly variations.
- **Necessary carbon for methane and methanol will be used from biomass waste before natural rotting or decaying.**

STRES is integral part in natural CO_2 and water cycle

Proposed STRES has no GHG emissions, because water and CO_2 are **recycled by solar irradiation** and photosynthesis.

It is based on distributed generation and use of solar exergy in all forms (SWWBG), with great help of IIoT.

System include Nobel price laureate prof. dr. Olah idea of „methanol economy“ (2006).

STRES and Carbon Recycling Society

- Proposed STRES enables smooth transition to a sustainable **“organic carbon recycling society”**.
- STRES is also sustainable part of promoted **“circular economy”**.
- Costs of all form of renewable exergy will be in beginning of transition period **higher**, but at the end of **transformation** to **STRES costs** will be lower and long-term stable.*
- Political and social implication on the world will be substantial leading to **„living well within the limits of the planet Earth“.**

* http://dx.doi.org/10.1016/j.joule.2017.07.005

How the proposed SES comply with the 6 requirement?

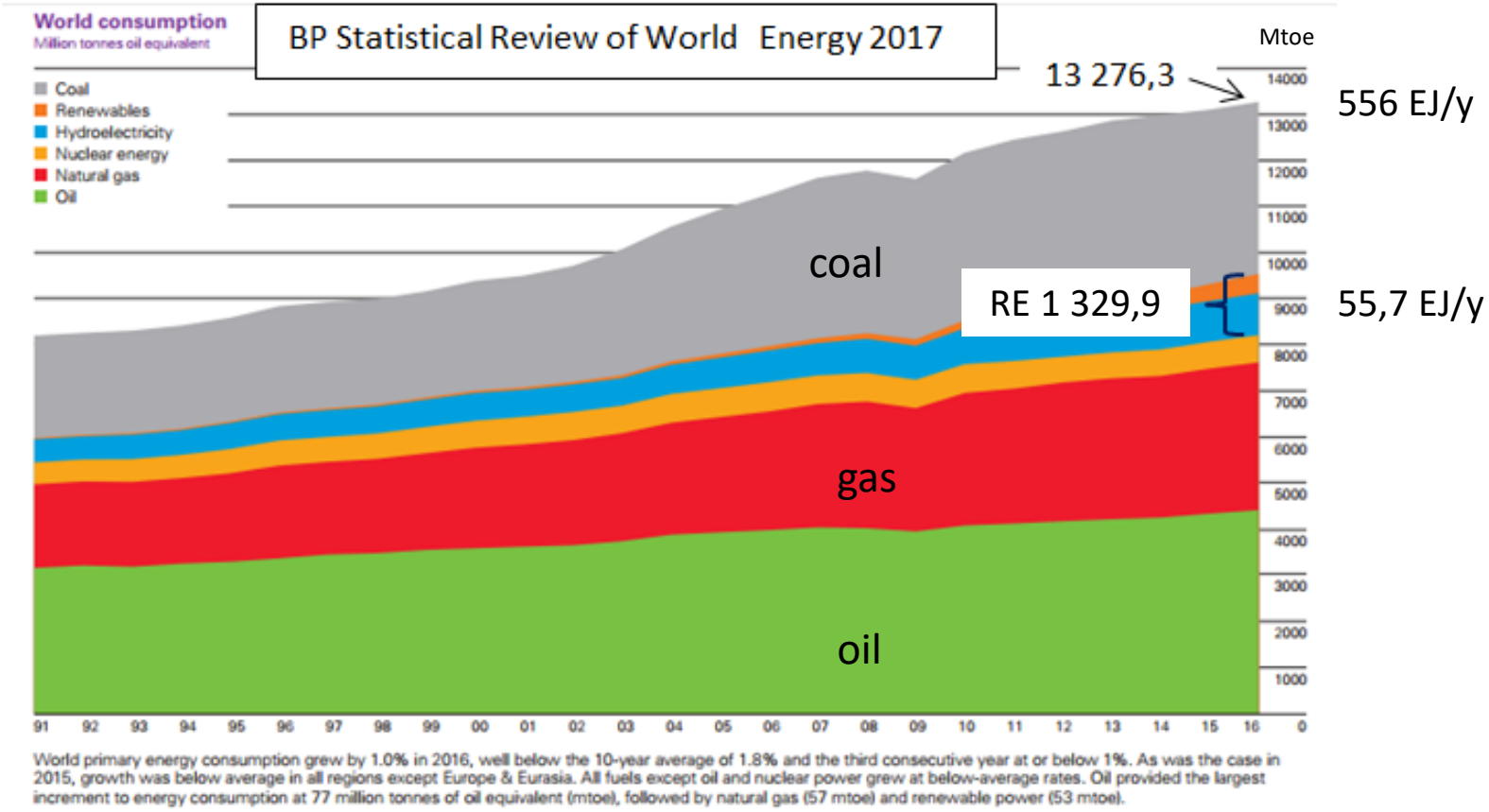
1. Primary exergy sources - solar energy in all forms and biomass – are everywhere available;
2. No emission of GHG;
4. Proposed exergy carriers can be used any time on any place; For proposed system we don't need a new infrastructures

   (power lines, gas pipelines, liquid storage also exist)
5. All exergy carriers can coexist with the present energy system
6. Should be competitive: According to IMF report the world fossil fuel pre-tax subsidies in 2013 have been $480 billion/y post-tax subsidies $1.9 trillion/y. Including the $1.4 trillion/y environmental damages, total direct and indirect costs, not included in the price of fossil fuels used are

   $ 2.78 $trillions/y. (5.3 $trillions/y after IMF data 2015)

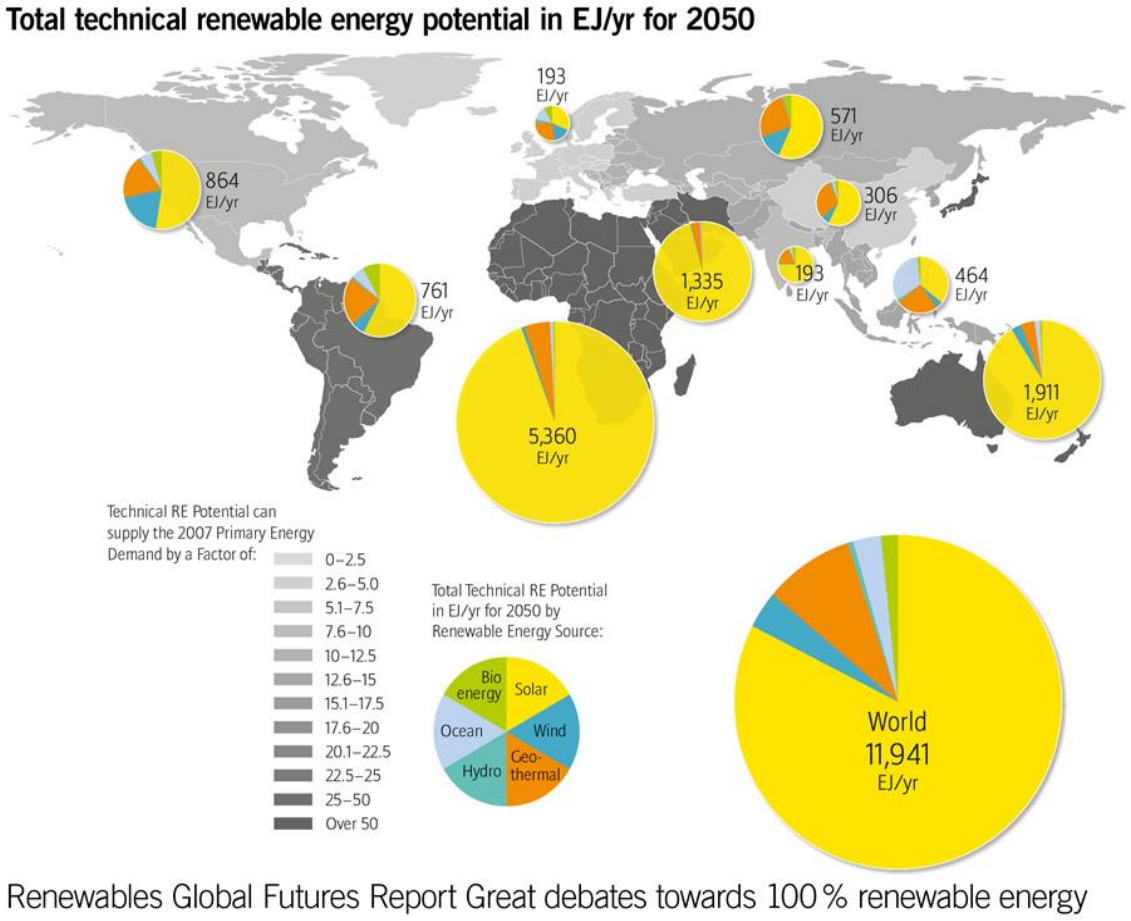
Including this subsidies in the final price of fossil fuels, competitiveness of RE will be out of question.

Is fossil fuel replacement in next 33 years viable and possible?



For next 33 years RE growth has to be ~ 290 Mtoe/y to achieve 80% lower GHG emissions on the world. RE growth 2015/2016 was only 80 Mtoe/y.

Do we have enough exergy resources?



Renewables Global Futures Report Great debates towards 100 % renewable energy

Available technical potential: **11.941 EJ/y**
Needed exergy
~556 EJ/y in year 2016
Needed exergy **2050**
~800 EJ/y
This is 6,7% of technical potencial.
According the IEA Report 2017 RE have to grow 700 TWh/y

REN21 Renewable Energy Policy Network for the 21st Century

Based on present known RES and technologies fossil fuel replacement is only the question of political will.

Carbon world resource from biomass for methane and methanol

A: Carbon stocks on the world are 500 billion tons of carbon

(IPPC, tier 1, Global biomass carbon map, 2000).

Yearly amount of carbon in growing biomass is:

C ~ 105.10^9 t C/y (carbon, dry mater)

https//:en.wikipedia.org/wiki/Biomass, 11.11.2013

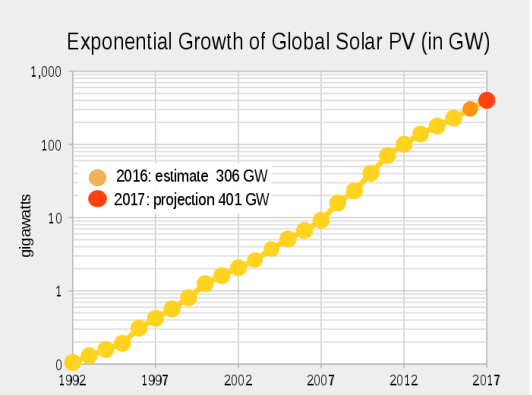
divided in two parts: 50% onshore and 50% offshore.

B: Carbon needed for methane (50%) and methanol (50%) production replacing present fossil exergy use (~500 EJ)is:

C = ~7.10^9 t/y or **13,33 %/y of available stocks**

using only onshore biomass. 86.7% of biomass yearly increase can stay in woody biomass and soil as food for microbiota.

Hydrogen production



- Hydrogen needed for conversion of biomass to new energy carrier is: ~**1,16.10^9 t H_2 /y**
- If we use the water for hydrogen production, we need for electrolysis10,22.10^9 t/y of water or 0,03 % of yearly world precipitation on the land (~ 33,6.10^{12} t/y*).
- For hydrogen production needed renewable electricity (at present 55 kWh/kgH_2): ~ 63.690 TWh/y and installed power of PV = 53.075 GW (yield:1200 kWh/kW, y).
- Expected installed PV in 2017: 95 GW/y ; total world installed capacity < 400 GW.
- Oxygen is a surplus product (part can be used for biomass to methanol conversion

- **Conclusion:** Natural resources for STRES are in abundance and can fulfill our expectations.

*Pidwirny, M. Global Distribution of Precipitation. *Fundamentals of Physical Geography, 2nd Edition*. 17 April 2008.

Where we stand with technologies?

How long is the EPT?

How big is the EROEI ?

Latest news: New Technology for liquid fuel production

1. Singapore's NUS researchers develop alternative ethylene production using solar energy.

2. Tiny metallic-gold particles are being used to convert sunlight into fuel.

E for Exergy !

EPBT and ERORI data for some RE technologies

Tecnology	EPBT (years)	EROEI LOW	EREI HIGH	COMMENTS
PV	0.2÷0.4	3	6 (28)*	*EPBT 0,2
WIND	0.2÷0.5	18 (offshore)	34÷ 18 (onshore)	Cf ~ 0,35 ÷0,19
HYDRO RESERVOIR	1 ÷ 1.5	205	280	Long life time
HYDRO RUN OF	0.5÷1 small 1÷1.5 large	170	267	Long life time
BIOMASS WASTE	0.3÷0.5	10	27	

All this technologies are sustainable, having **EROEI more than 1**

Important to know:

Solar irradiation conversion efficiency to biomass and biofuels is very low, but photo synthesis is natural, cheap process!

- Present conversion efficiency from **solar irradiation** over sugarcane to **bioethanol** per ha area (average yield of bioethanol: ~6000 l/ha) in real conditions* is under

  ExE ~ 0,0032%.

- Further conversion of ethanol to electricity with TPP efficiency 50%, give us the total efficiency of solar irradiation use over the biomass, under 0,0013%.
- For comparisons efficiency of PV system, with present technology, on the same area is ~16% (1:640 for bioethanol and 1:1300 for electricity).

Conclusion: Biomass should be used very carefully, evaluating total chain of exergy transformation to find the final exergy efficiency.

*Novak P.:2012, EEA SC Opinion on GHG Accounting in Relation to Bioenergy, Biodiesel, 2012, Krakow, Poland

STRES for future development of transport technologies

- Heavy vehicles and tractors, passenger airplaine can not be electrified in near future. They can used s-methane and s-methanol.
- Electric cars:
  - Pro: More efficient conversion of the electricity (59%–62%) in mechanical work in comparisons to ICE (19-20%).
  - Contra: Create a new environmental problem with batteries production and recycling (according the „Guardian report“, we have to deal with 11 millions ton of batteries for recycling up to 2030).
- Hybrid cars with sinthetic fuels are solution for transition period.
- Fuels in STRES enable further use of ICE engines, with high efficiency and near zero emissions.

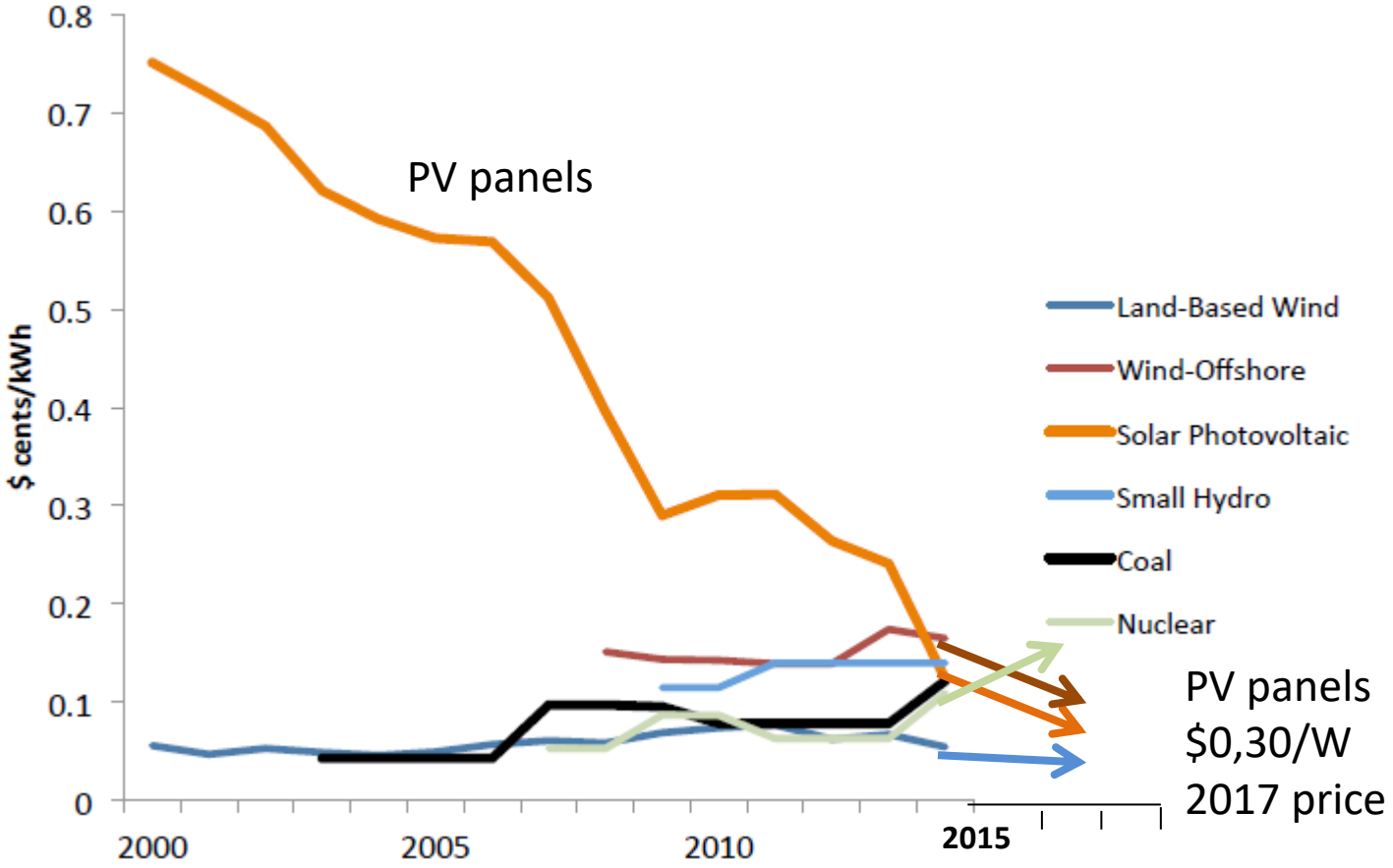
Economy: RE and GDP

The world will manage the shift to a renewable future **without increasing overall annual energy expenditure**, meaning that the future energy system will require a smaller share of GDP.*

* - Latest report from DNV – GL: ENERGY TRANSITION OUTLOOK, 2017

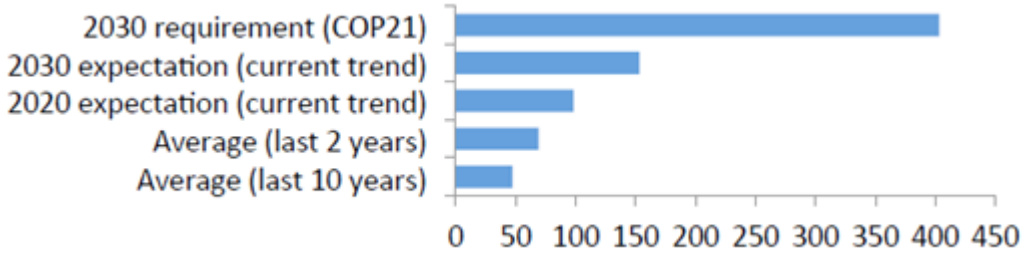
- Jacobson M.Z. Et all: 2017, 100% Clean and Renewable Wind, Water and Sunlight Alll- Sector Energy Roadmaps for 139 Countries of the World, Joule 1, pgs. 108-121, Elsevier Inc.

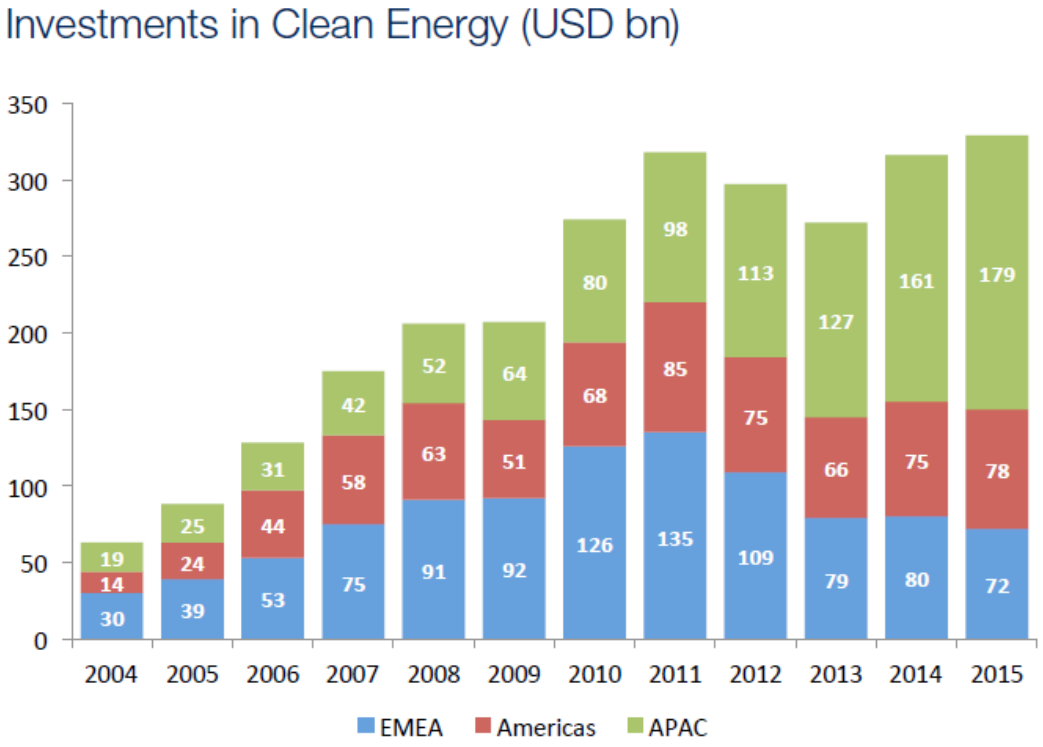
Levelized Cost of Energy (World Average)



Source: OpenEI, Transparent Costs Database

Investment in RE





Source: Bloomberg New Energy Finance

Investment in RE are growing, but still are not sufficiend

Conclusions

- Exergy efficiency EE and EROEI are good quality indicators of conversion processes
- Proposed STRES can replace the present system with further development of chemistry for biomass conversion in methane and methanol, solving the storage problems.
- STRES based on renewable electricity open also the ways to P2G (Power to Gas) and P2L (Power to Liquid) technologies with many thousands of new jobs.
- HVAC systems adaptation will be very easy, using HP with storage or standard gas or liquid fuels appliances.