1st Energy Tech Forum

April 1, 2016

ENERGIA.gr

Energy:
From Great Challenges to Innovative Solutions

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aptL AEROSOL & PARTICLE TECHNOLOGY LABORATORY

CPERI Chemical Process & Energy Resources Institute

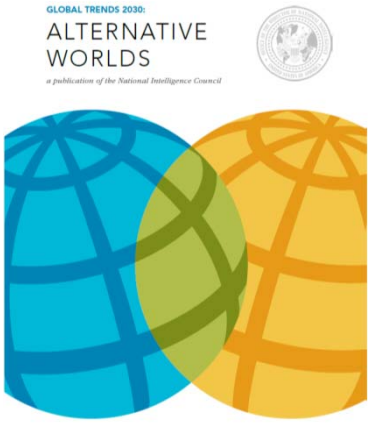
CERTH CENTRE FOR RESEARCH & TECHNOLOGY-HELLAS

GLOBAL TRENDS 2030:

ALTERNATIVE WORLDS

a publication of the National Intelligence Council

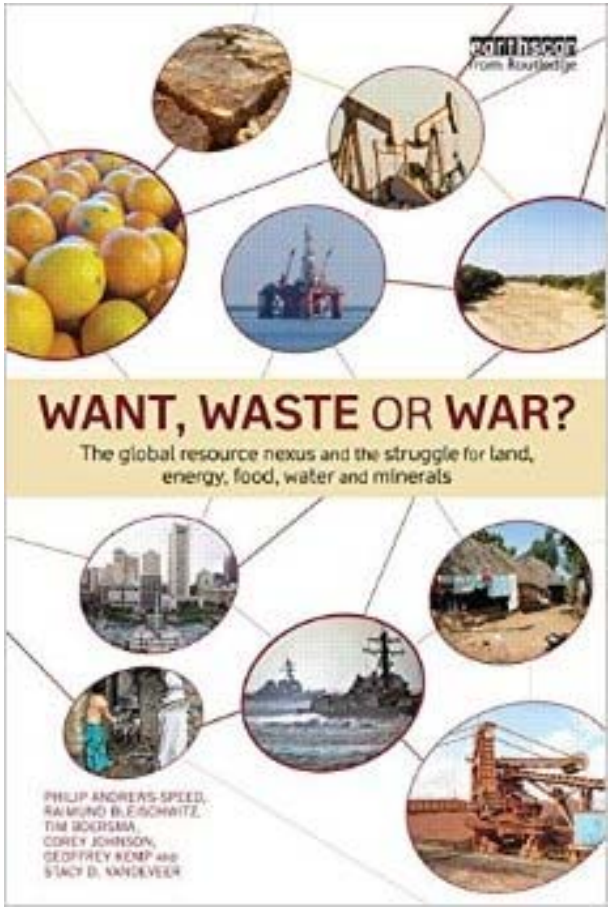
December 2012



MEGATRENDS	
Individual Empowerment	Individual empowerment will accelerate owing to poverty reduction, growth of the global middle class, greater educational attainment, widespread use of new communications and manufacturing technologies, and health-care advances.
Diffusion of Power	There will not be any hegemonic power. Power will shift to networks and coalitions in a multipolar world.
Demographic Patterns	The demographic arc of instability will narrow. Economic growth might decline in "aging" countries. Sixty percent of the world's population will live in urbanized areas; migration will increase.
Food, Water, Energy Nexus	Demand for these resources will grow substantially owing to an increase in the global population. Tackling problems pertaining to one commodity will be linked to supply and demand for the others.

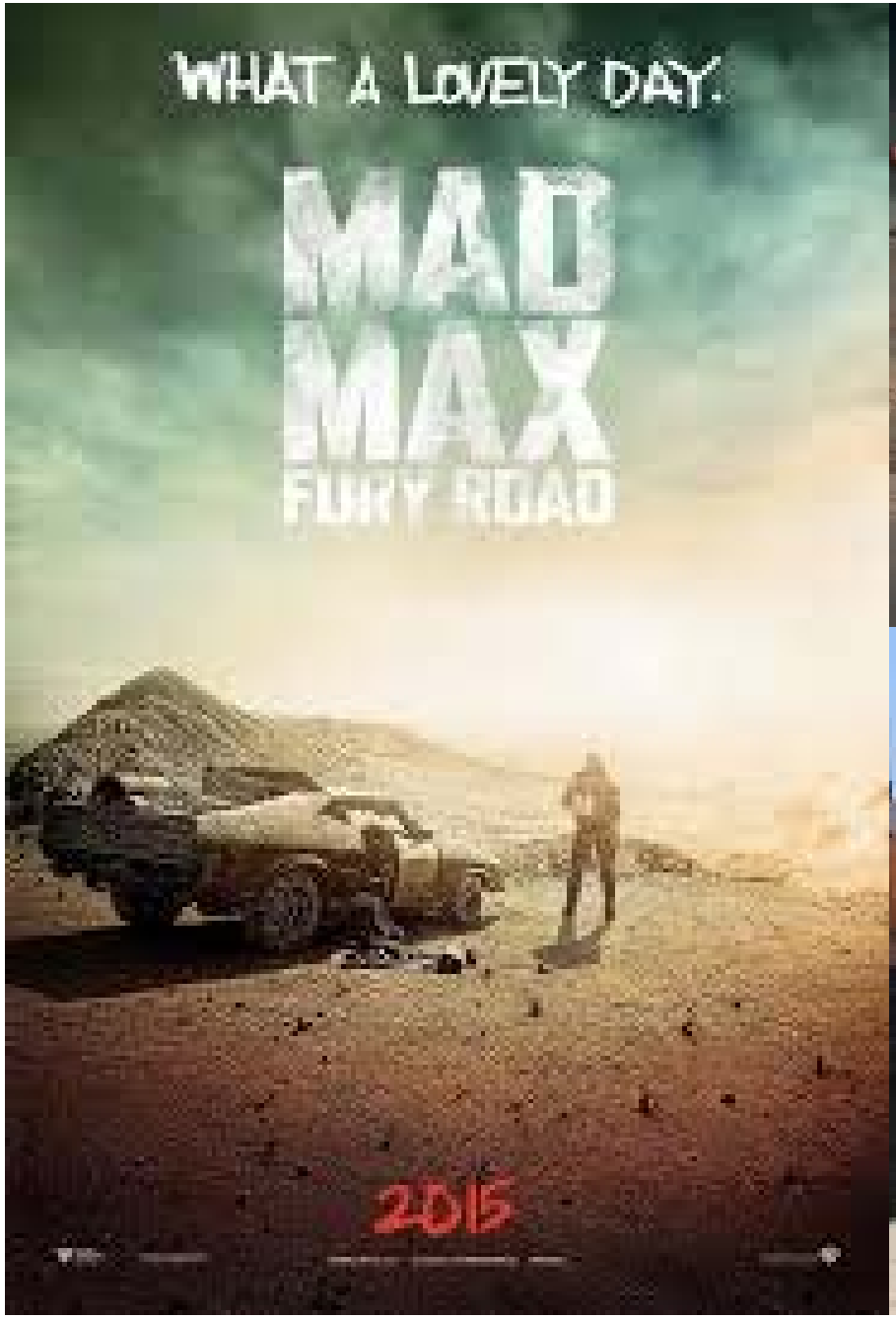
Want, Waste or War?

The Global Resource Nexus and the Struggle for Land, Energy, Food, Water and Minerals



…governance that fails to address the complexities of the resource nexus can lead to more waste, more want, more wars. If, however, a nexus approach is applied to achieve better governance, these effects of global resource use can be mitigated.

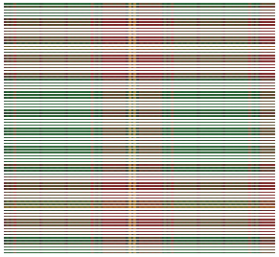
P. Andrews-Speed et al. (2015)


WHAT A LOVELY DAY.
MAD
MAX
FURY ROAD
2015


WASTELAND

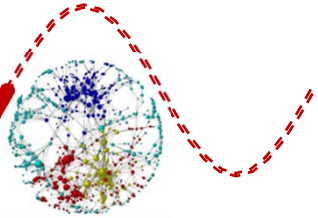
1st Industrial Revolution | 2nd Industrial Revolution | Service Society | Knowledge Society | Holistic Age

Collective-ness…… Individuality…… «Connected-ness»



Clothing | Mass Transport | Mass Consumption | Information Communication | Environment/Energy Health/Food

England | Germany | USA | Japan | ????



1800 | 1850 | 1900 | 1950 | 2000

Water/Steam
- Steam Engine
- Textile Industry

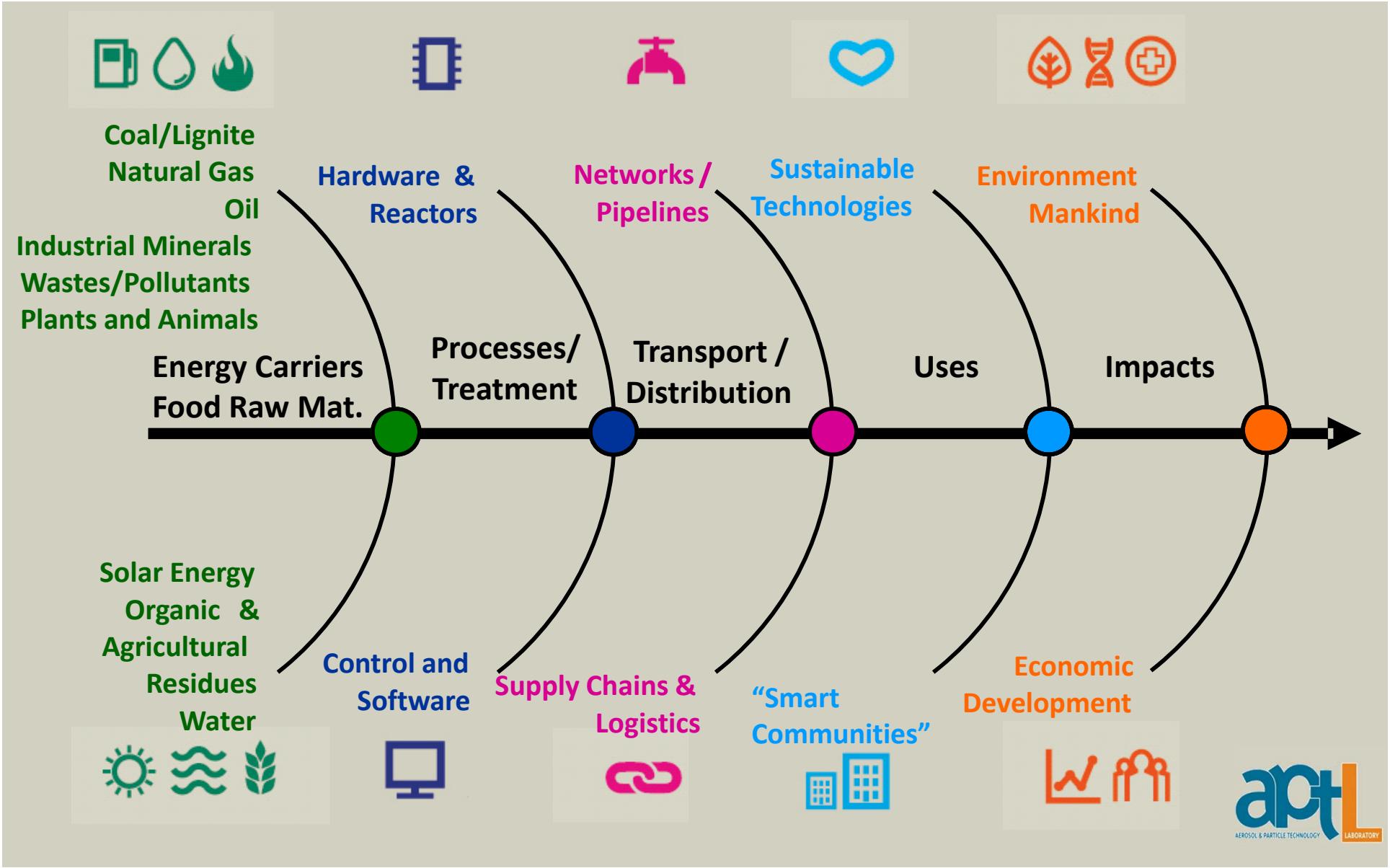
Steel
- Rail Road

Polymers
Alloys
- Electric Appliances
- Chemical Industry
- Cars
- Petrochemical Industry

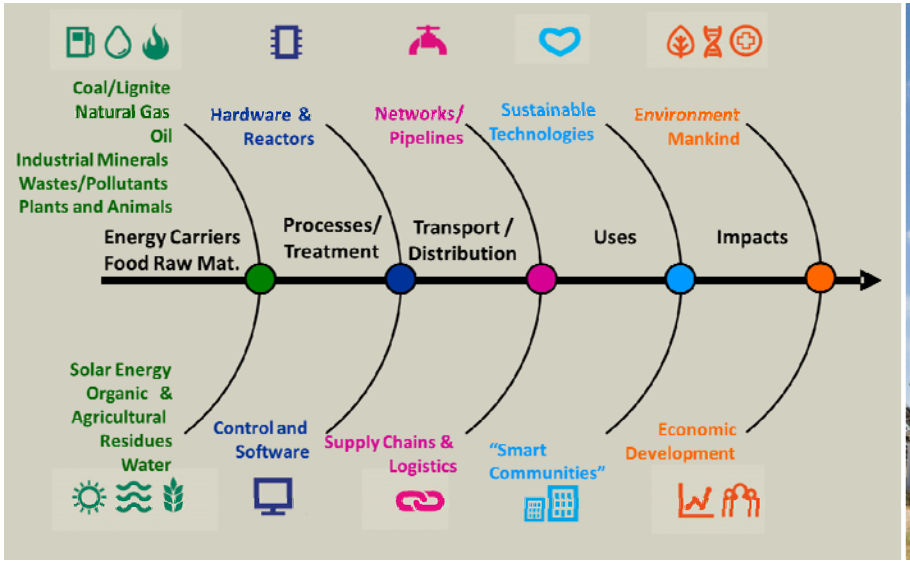
Ceramics
Semiconductors
Composites
- Information Technologies
- Electronics/Automation
- Internet/Mobile Communications

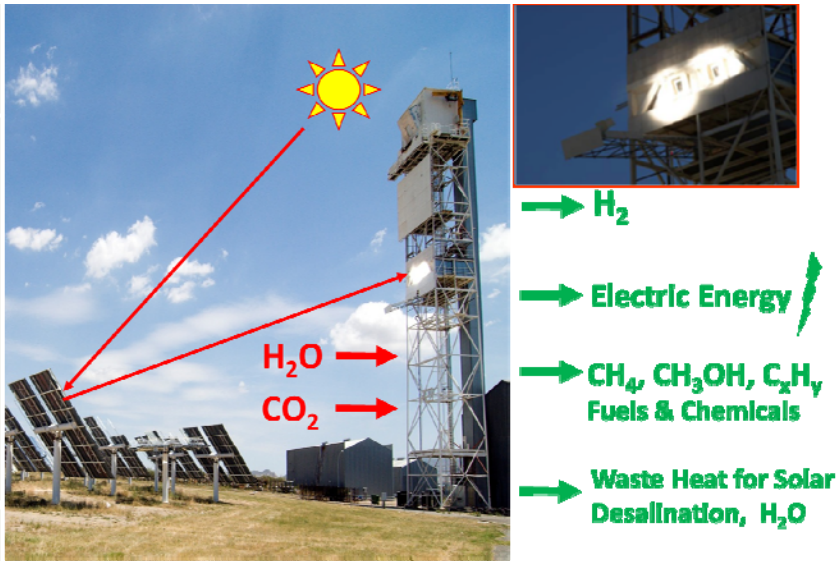
Nanomaterials
????
- 3D Printing
- ????

A Holistic Approach: PROMETHEUS
Sustainable Technologies ("Generalized Energy") Corridor

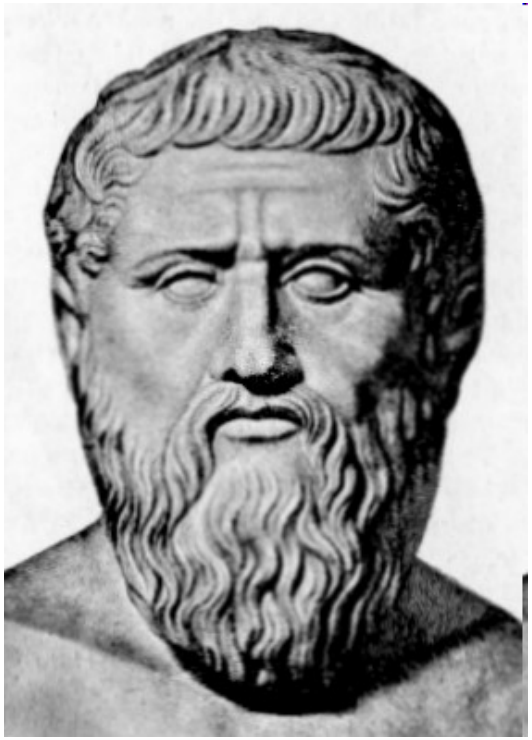


A Holistic Approach to Sustainability
The Concept of the "Generalized Energy" Corridor





The Challenge of Sustainable Development



"…γῆ μὲν ὁπόση πόσους σώφρονας ὄντας ἱκανὴ τρέφειν, πλείονος δὲ οὐδὲν προσδεῖ…"
Πλάτων, Νόμοι, 360 π.Χ.

"…The land must be sufficient to support no more than a certain number of people living with moderation…"
Plato, Laws, 360 B.C.

Individual Success is Difficult…



Only 1 out of 1000 baby turtles makes it to the sea…

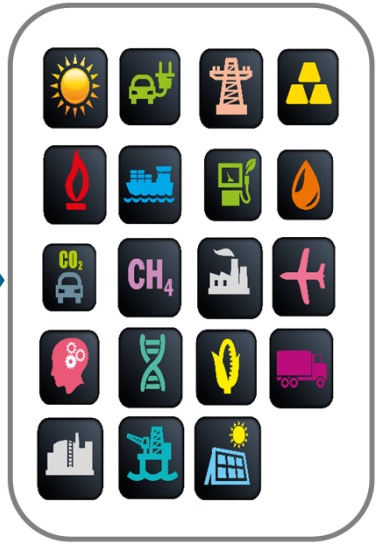
Networks of Dynamic, Social, Non-linear Innovation

The Power of CLUSTERS!

KNOWLEDGE CREATION & TRANSFER

NOVEL PRODUCTS AND NEW MARKETS

CHORUS
Clean Energy *cluster*

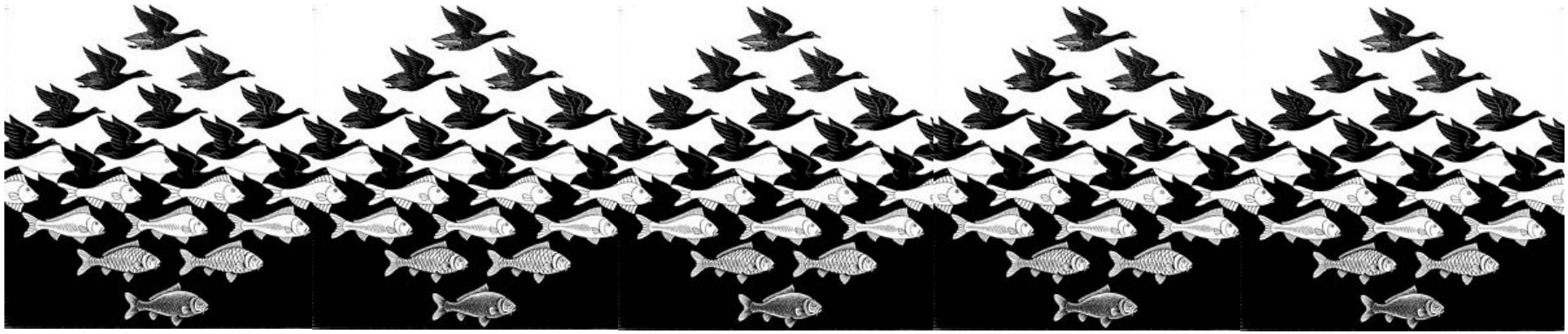


RENEWABLES

LOW CARBON PROCESSES

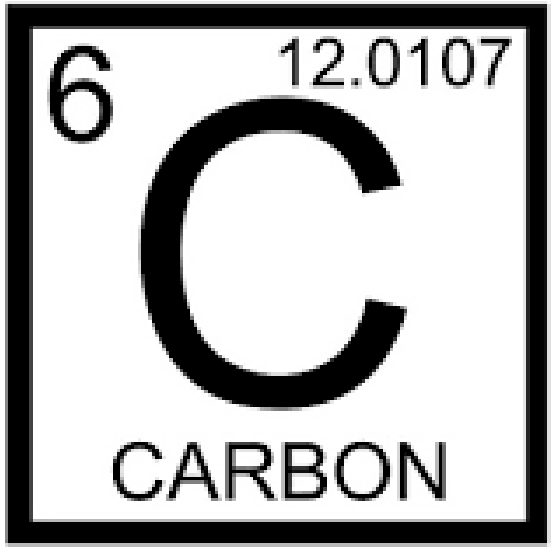
ENERGY EFFICIENCY

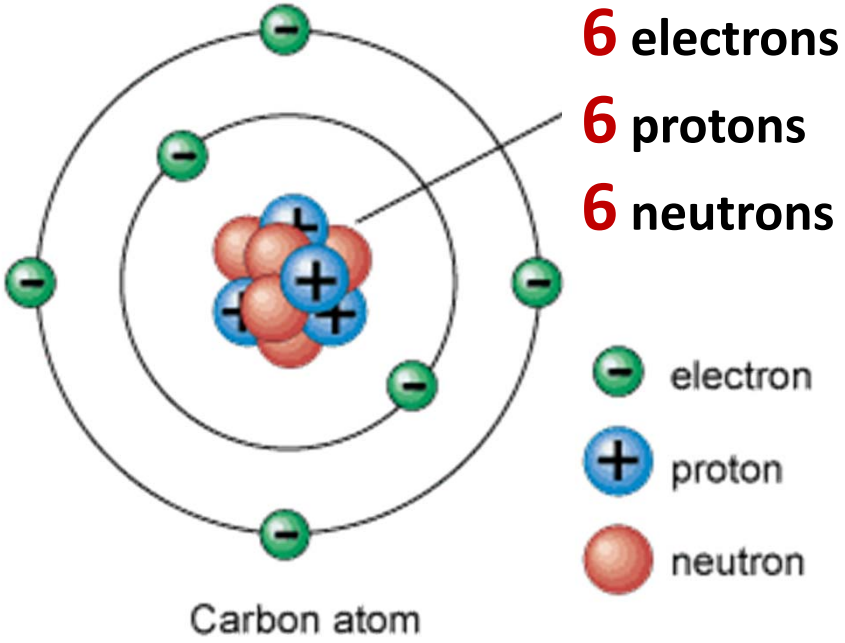
EMISSION CONTROL



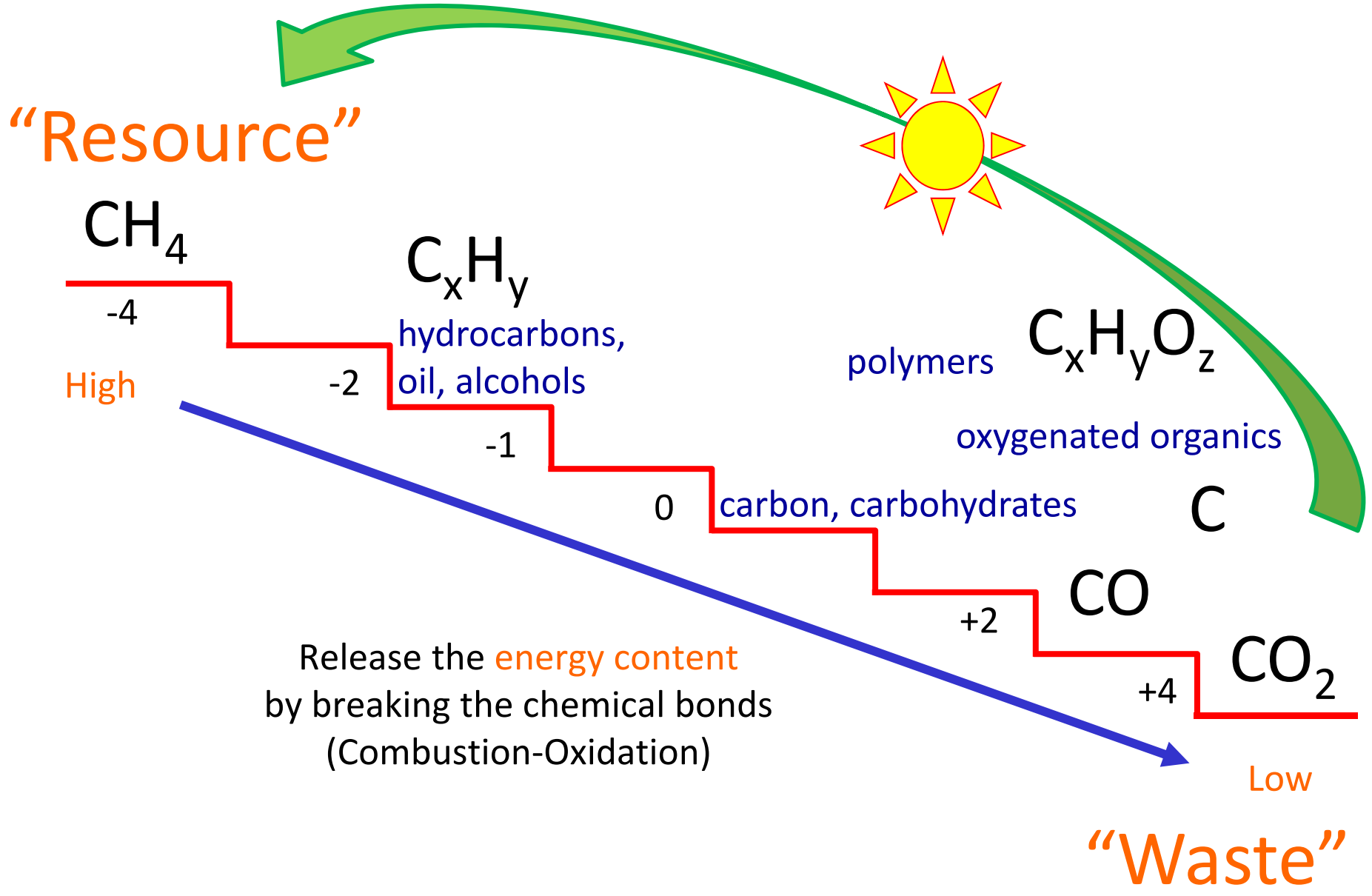
Backbone for Regional Growth

Why the Carbon Economy is so Resilient?



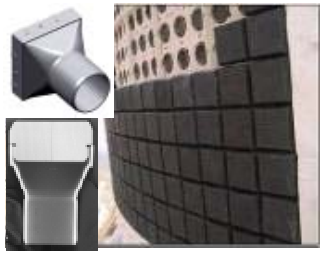


Carbon Cyclic Economy



Solar Thermochemical Technologies

SOLAIR

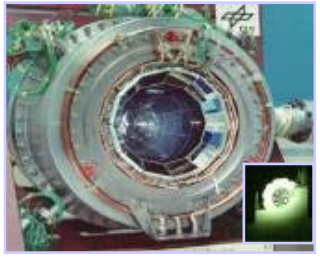


Solar Volumetric Receiver

HYDROSOL
HYDROSOL II

Solar H_2 from H_2O splitting

SOLREF
CONTISOL



Solar CH_4 Reforming

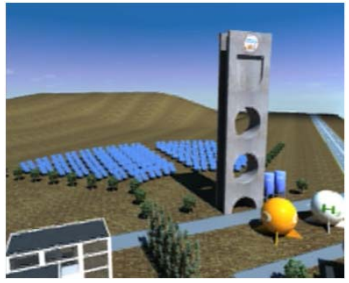
SOLHYCARB

CH_4 Solar Cracking

NANOREDSOL
HYDROSOL+

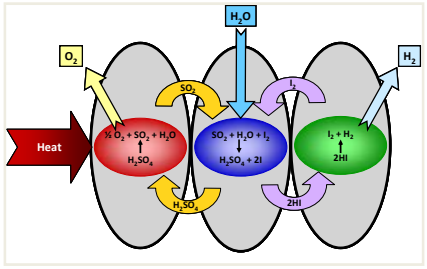
Solar Reactor manufacturing

HYDROSOL-3D
HYDROSOL-PLANT



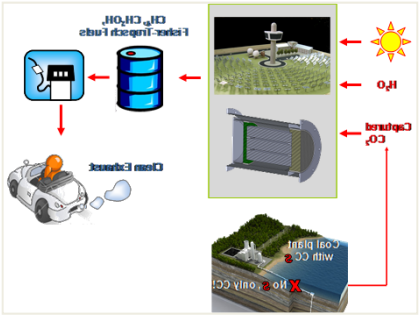
Solar H_2 Plant Design & Realization

HYCYCLES



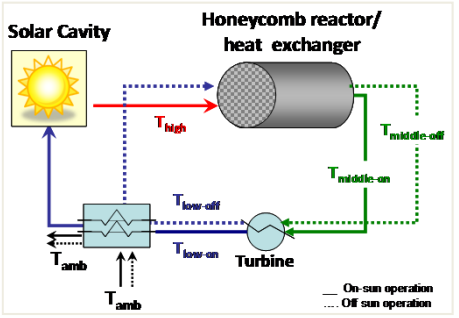
Solar Sulfur-Iodine Cycle

ARMOS
CARDIOSOL



Carbon Neutral Solar Fuels

RESTRUCTURE
STORRE
NESTOR



Thermochemical Storage of Solar Energy

Key Enabling Technology: Redox Materials

Oxidation of reduced oxide

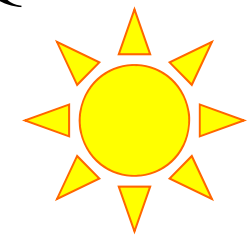
$$M_xO_{y-\delta} + \delta \begin{cases} H_2O \rightarrow \delta H_2 + M_xO_y \\ CO_2 \rightarrow \delta CO + M_xO_y \\ 1/2O_2 \rightarrow Q + M_xO_y \end{cases}$$

} Solar Syngas (H_2+CO)

Thermal reduction of oxide

$$M_xO_y + Q \rightarrow M_xO_{y-\delta} + \delta/2O_2$$

Heat storage



Solar Fuels Technology Evolution

HYDROSOL-I

3 kW, first production of solar H_2

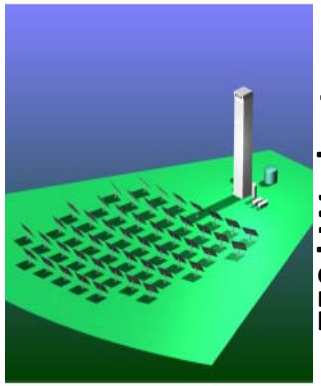
3 kW x 2, continuous H_2 production

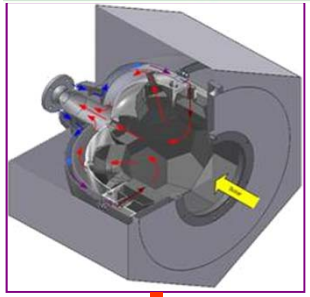
HYDROSOL-II

100 kW X 2, pilot plant

HYDROSOL-3D

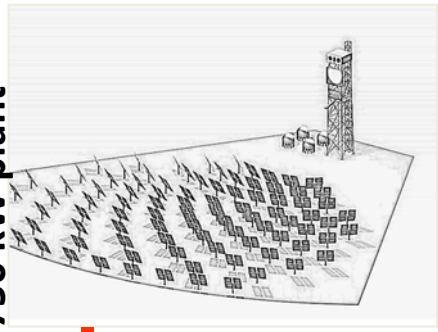
1 MW plant design





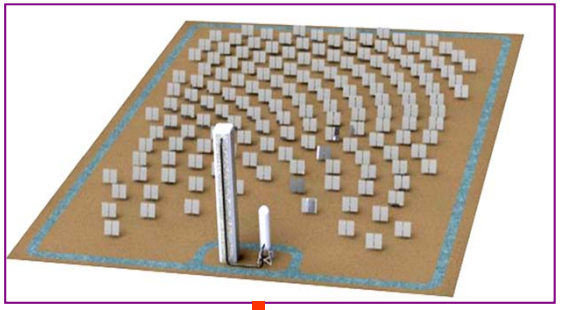
HYDROSOL-PLANT

750 kW plant



PROMETHEUS

1 MW installation



2004 JAPAN EXPO 2005

2005 IPHE 2006

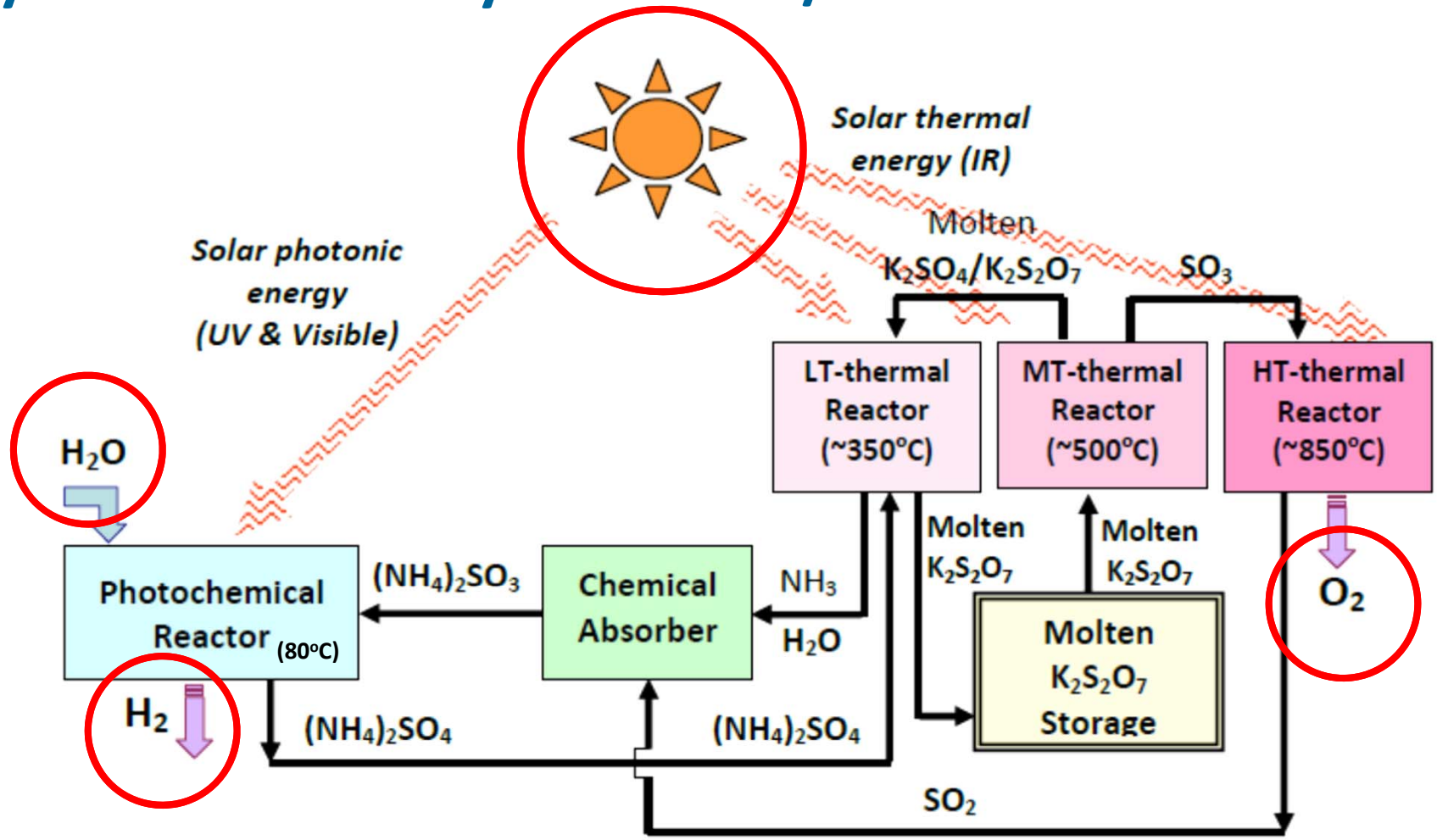
2008 Descartes Prize 2007

2011 ERC IDEAS Award 2010

2015 Taipei Inv. Tech. 2014

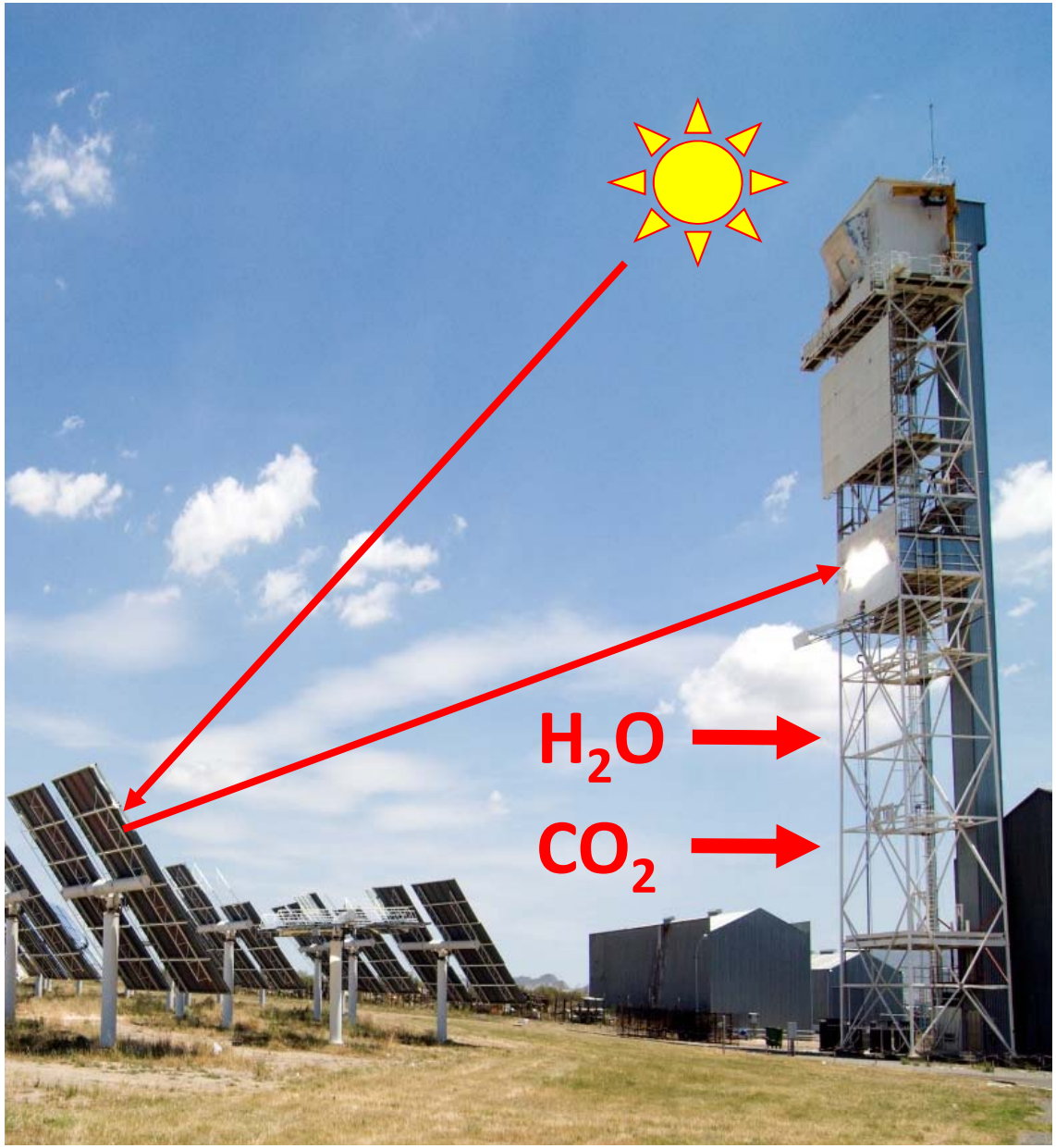
2017 H2020 Success Story 2016

Hybrid Ammonia Cycle: Photo-/Thermo-Chemical



- In collaboration with TAMUQ/QNRF in Qatar
- Novel reactor concepts

Carbon Neutral Solar Fuel Plant



→ H_2

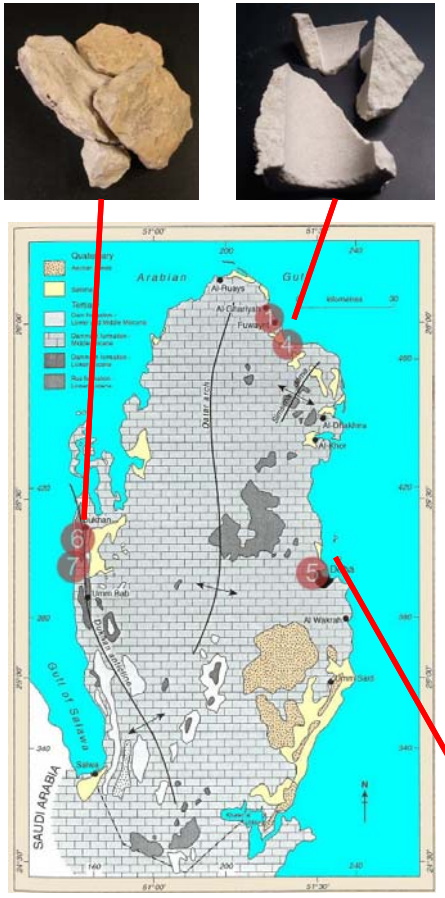
→ Electric Energy

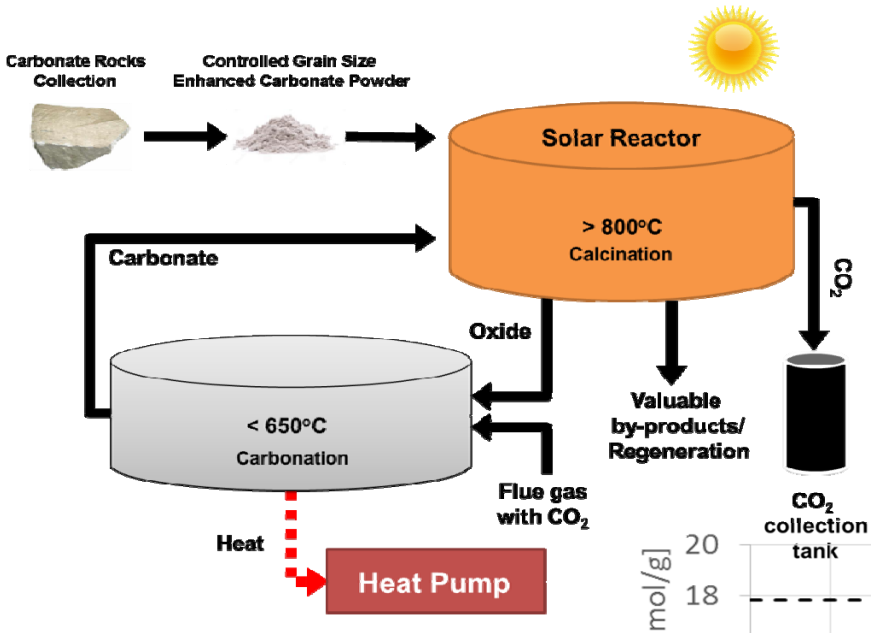
→ CH_4, CH_3OH, C_xH_y
Fuels & Chemicals

→ Waste Heat for Solar Desalination, H_2O

Thermochemical Energy Storage in Minerals

$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$, $\Delta H = 178$ kJ/mol TES : 3.1 MJ_{th}/kg_{CaO}

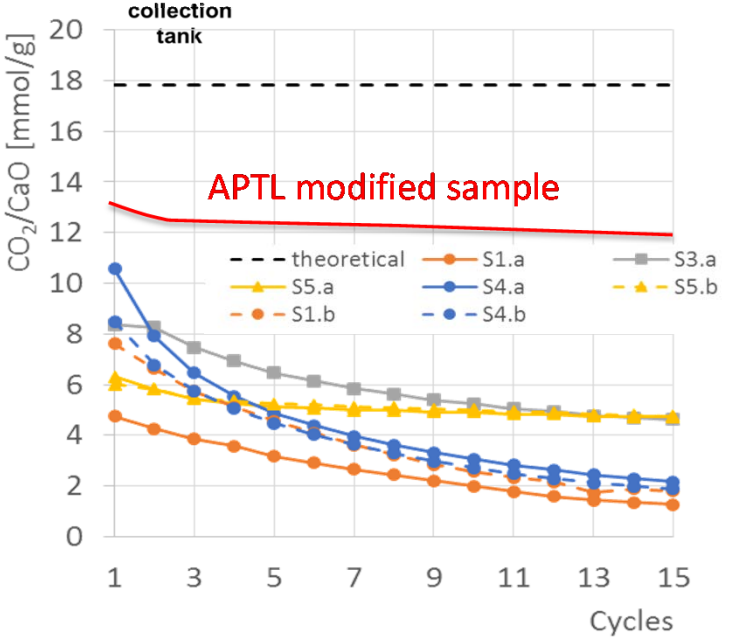




- In collaboration with TAMUQ/QNRF in Qatar

East S5

(Metro)



Concluding Remarks

- Grand Challenges require holistic approach and synergies
- Sun+Water+Mineral Resources = Sustainable Prosperity
- Novel Solar Thermochemical Technologies for energy, solar chemicals (H_2 , C_xH_y…), water and material recovery are now at a Technology Readiness Level (TRL) which makes them suitable for pilot/demonstration projects.
- Let’s face the challenges with innovative solutions!

Acknowledgments

- **The European Commission for supporting our research in combustion engines, emissions, hydrogen and solar fuels** through >45 projects over the last 20 years and in particular current projects: ARMOS and HYDROSOL-PLANT
- **The Greek Secretariat for Research and Technology** for supporting our research through projects KRIPIS-SYNERGIA and CHORUS Cluster.
- **Past and Current Industrial Partners** with special thanks to Molycorp, Tenneco, Ibiden, Honda, CR Fiat, AVL and CERTAM.
- **My colleagues at APTL**

Thank you for your attention!

20 YEARS apt LABORATORY
AEROSOL & PARTICLE TECHNOLOGY
1996-2016

20th Anniversary Celebration Conference

Plenary Speaker:

Prof. David Kittelson (Univ. Minnesota)

Selected Papers will be published in

INDICATIVE TOPICS

- Clean Engines & Emission Control
- Low/Zero-Carbon Energy
- Solar Fuels and Hydrogen
- Nanoparticle Technology
- .....

FEATURING

- Panel Discussions
- Technology Exhibition
- Facility and Lab Tours

Save the Date:
Thessaloniki, Greece
June 2-3, 2016