ENERGY

Principles and Practice of P_3

Extracting Entrepreneurial Innovation Opportunities for Social Businesses Pursuing Ethical Profitability

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Auto-ID Labs, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Social Business *is also about*

Leapfrogging the barriers of conventional wisdom and the dead weight of old technology.

Energy Design Metaphor

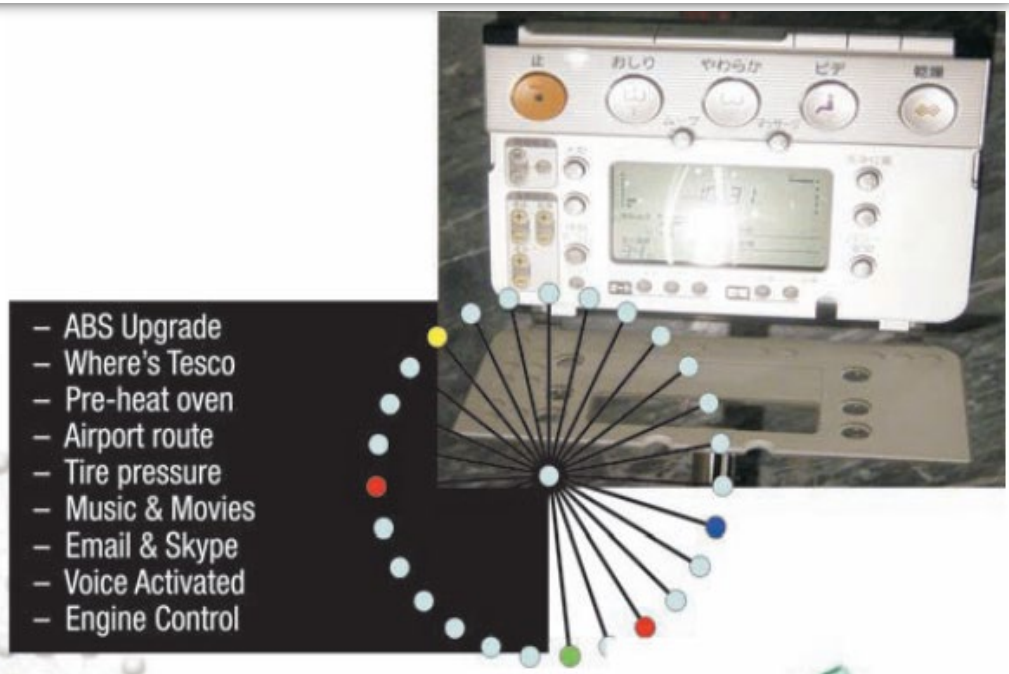
“Swappable Atoms”

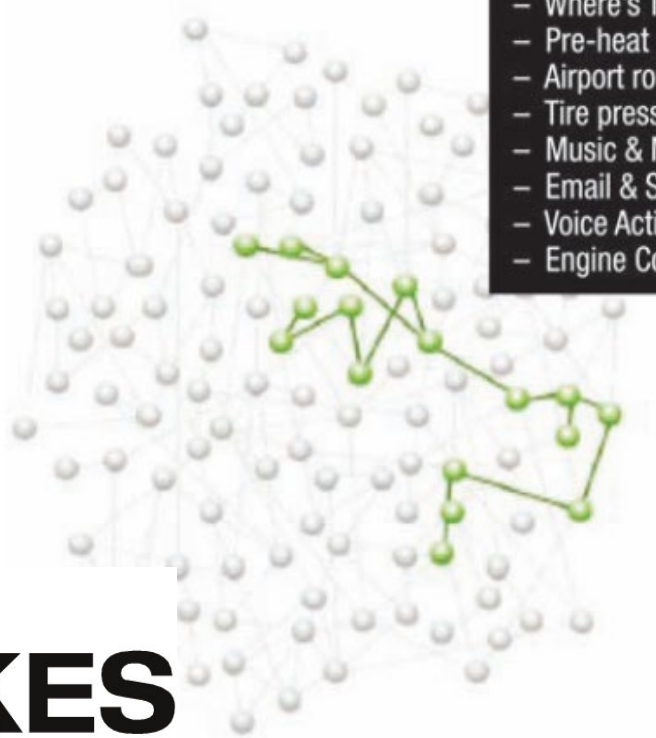
The Paradigm of Atoms to Bits

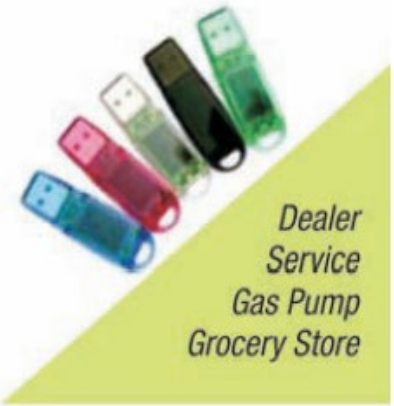
2005 – Swap form factor for “atoms” (connect bits, cars, engines, toilets)

12 years later, swappable car batteries are in discussion, but form factor for energy is still large.

On 17th November 2005, during a conversation in my office at MIT, I was requested to write a short article, on future trends in e-business, to be included in a publication to accompany the successful completion of the Tekes supported e-logistics program (ELO) in 2006. It was suggested that I send the completed article in about six weeks to allow for translation in Finnish.



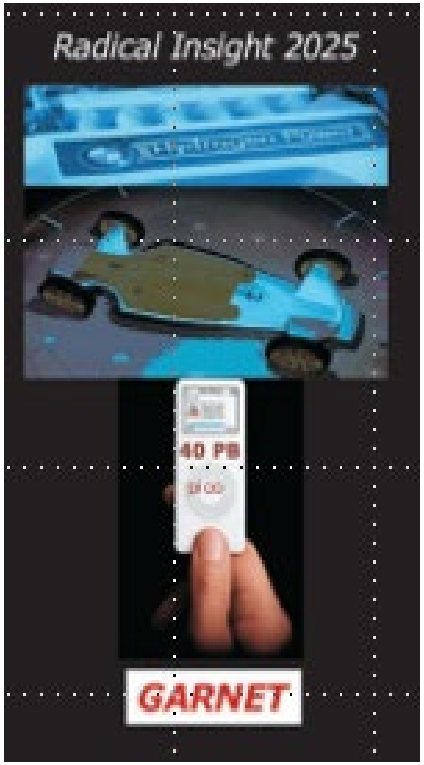




TEKES

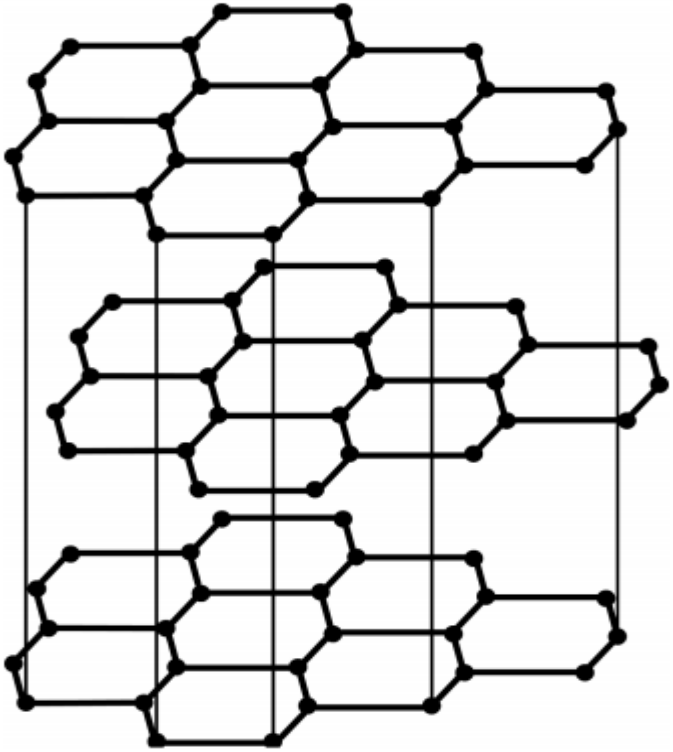
Swap "atoms" form factor – a different way of thinking about inventory at hand

12 years ago, the idea was of "portability" of atoms [eg: running your car on (metallic) hydrogen]



S. Datta, published (by TEKES in 2006)

https://dspace.mit.edu/handle/1721.1/56251



Wigner E. and Huntington H.B. On the possibility of a metallic modification of hydrogen. *J. Chem. Phys.*, 1935, v.3, 764–770.

Fig. 1: Schematic representation of the layered lattice of graphite. Wigner and Huntington [19] would propose that most energetically favorable form of metallic hydrogen would assume this crystal structure. http://www.ptep-online.com/index_files/2011/PP-26-07.PDF

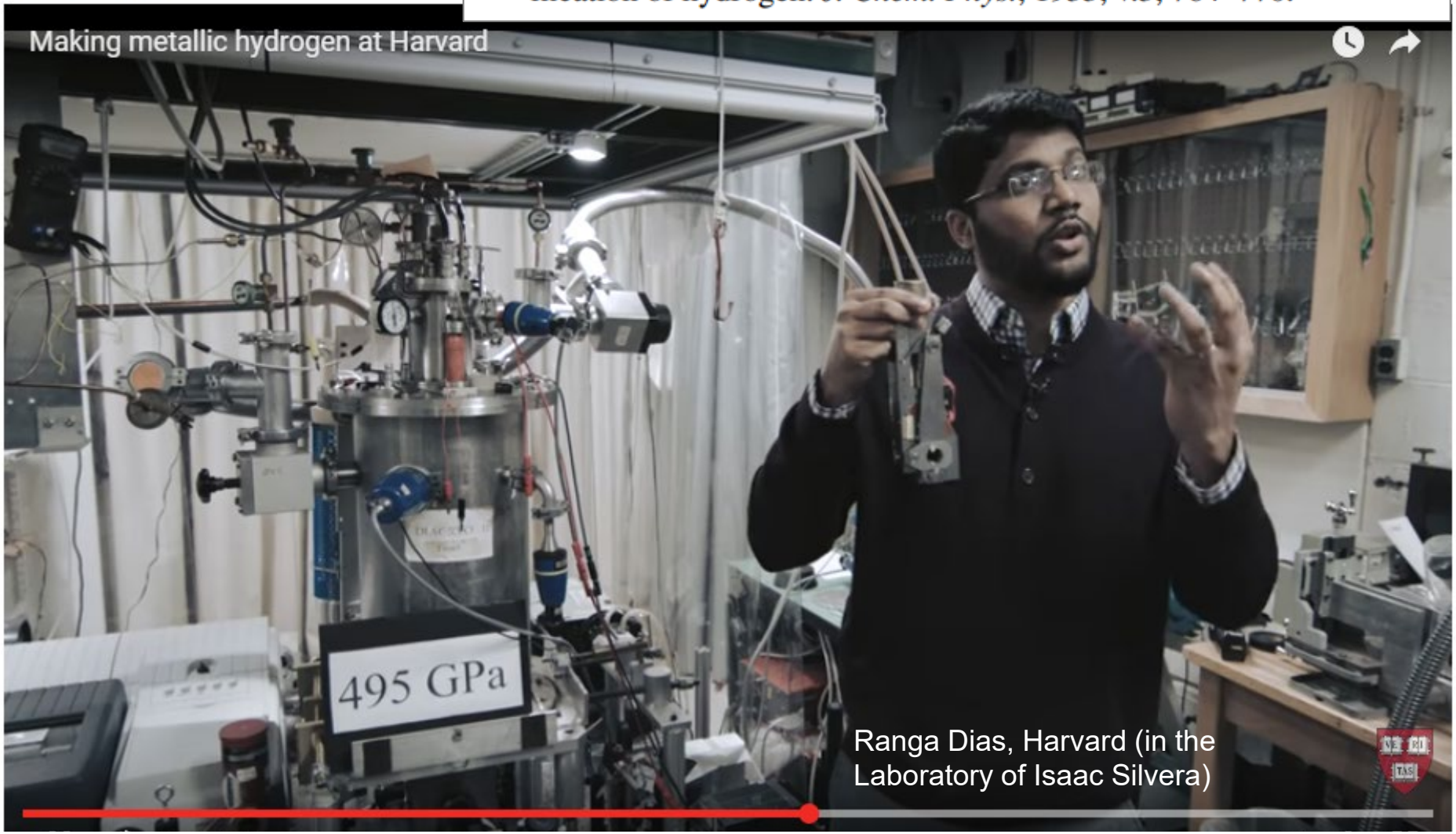
J. D. Bernal who first put forward the view that all substances go over under very high pressure into metallic or valence lattices" [19].

The rationale of "portability" of atoms was based on the theory of metastable metallic hydrogen

Harvard scientists announce they've created metallic hydrogen, which has been just a theory

January 26, 2017 |

19. Wigner E. and Huntington H.B. On the possibility of a metallic modification of hydrogen. *J. Chem. Phys.*, 1935, v.3, 764–770.



http://news.harvard.edu/gazette/story/2017/01/a-breakthrough-in-high-pressure-physics/

Swap "atoms" form factor – a different way of thinking about inventory at hand

12 years ago, the idea was of "portability" of atoms [eg: running your car on (metallic) hydrogen]

Drive any vehicle – car, ship, plane, rocket
Use metallic hydrogen in a USB drive form

Swap it anywhere to replenish

Think SCM - near-zero inventory of fuel, the weight of fuel, inventory carrying cost and energy used to carry inventory

https://dspace.mit.edu/handle/1721.1/56251

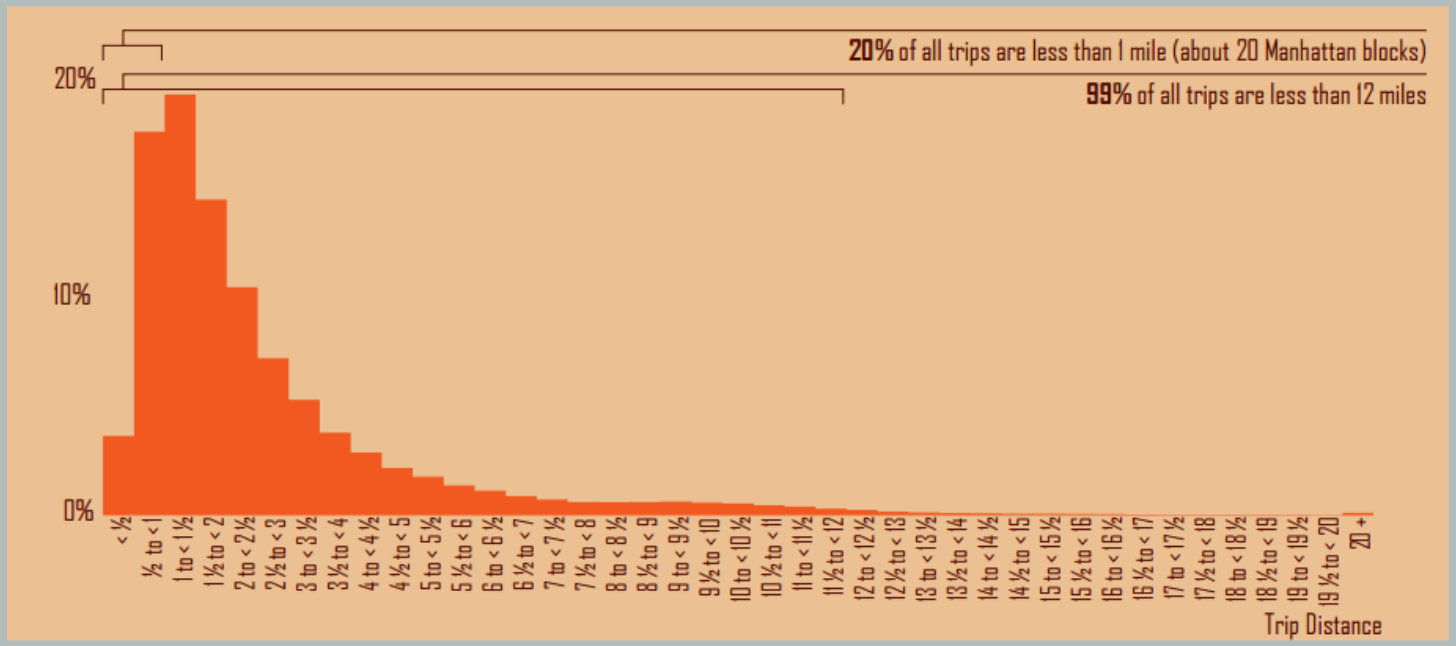
Swap “atoms” form factor – a different way of thinking about a typical taxi ride

http://www.nyc.gov/html/tlc/downloads/pdf/2014_taxicab_fact_book.pdf

Yellow taxis provide an average of

485,000
trips/day

The average trip distance is **2.6** miles



http://map.mathshell.org/download.php?fileid=1706

12 gallons

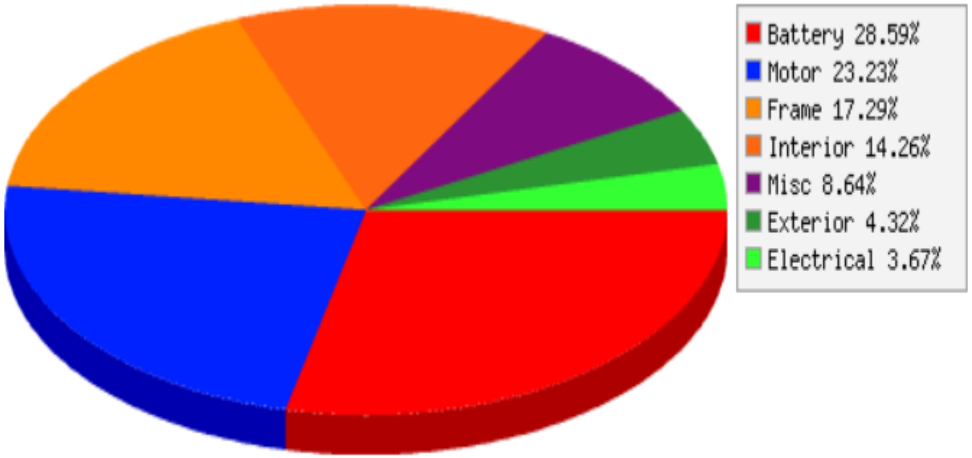
72 lb @ 6 lb/gal

Smaller cars generally have gas tanks that hold **12 gallons** worth of gas, while larger cars can hold 15 or **16 gallons**. For the purpose of this story, let's say gas costs $3.85 a gallon. A car with a **12**-gallon tank costs $46.20 to fill up while a larger car with a 15-gallon tank costs $57.75. Jul 5, 2013

How much energy (inventory) and weight of energy (gas or battery) is a vehicle carrying for an average 2.6 mile trip?

www.teslarati.com/tesla-model-s-weight/

TESLA MODEL S WEIGHT – 4,600+ LB



Battery Pack **1323 lb**

- 1323 lb (1)

Aluminum Space Frame

- ~ 800 lb

Motor / Drivetrain

- ~ 350 lb – electric motor + inverter
- ~ 175 lb – differential
- ~ 250 lb – wheels + tires
- ~ 120 lb – brakes calipers, discs, lines
- ~ 80 lb – air suspension

Interior

- ~ 200 lb – front powered seats + rears
- ~ 190 lb – windshield, windows, hatch
- ~ 150 lb – pano glass and assembly
- ~ 80 lb – carpet, padding, mats
- ~ 40 lb – dash, trim, panels

Exterior

- ~200 lb – doors, frunk, hatch, body

Misc

Swap “atoms” form factor – a different way of thinking about a typical taxi ride

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1300 lb battery for a 2.6 mile trip?

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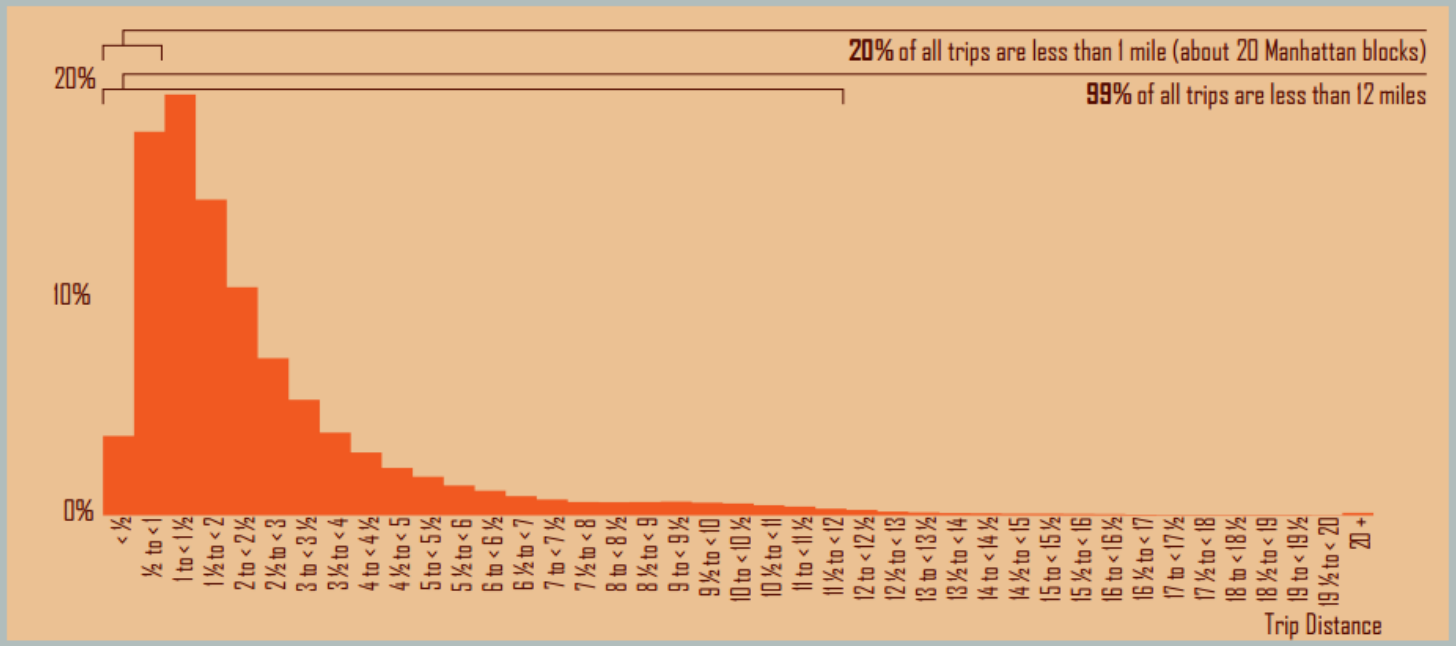

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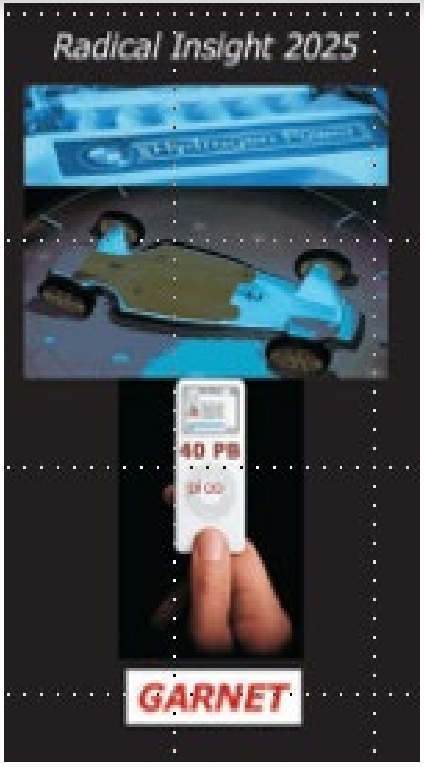
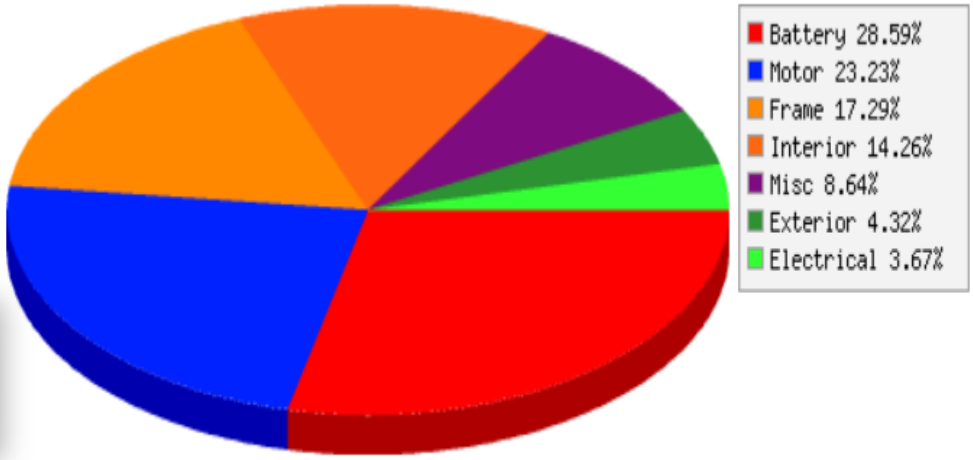
Change the equation!



10 gram Hydro-Stick
(Shoumen Datta, 2017)

TESLA MODEL S WEIGHT – 4,600+ LB



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Changed the equation!

https://qz.com/1001518/indias-electric-vehicle-revolution-will-begin-with-auto-rickshaws-running-on-swappable-batteries/

QUARTZ
India

EV, OR NOT TO BE?

India's electric vehicle revolution will begin with auto-rickshaws running on swappable batteries

https://qz.com/1001518

Changed the equation!

SWAPPABLE ATOMS

swappable

batteries

https://qz.com/1001518

Design Metaphor

“Swappable Atoms”

Atoms to Bits

Swap “atoms” form factor – Hydro-Stick of metallic Hydrogen is not a panacea

The form factor of energy, and its source, for transportation, may undergo many radical metamorphoses because one solution may not suit all the different type of needs.

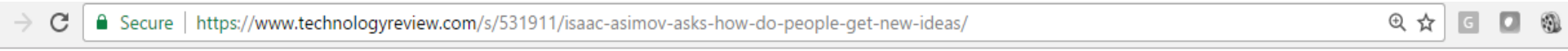
New ideas. New solutions. New engineering.

5 MB hard drive being shipped out of IBM (1956)

IBM 5 MB hard drive transported by PanAm (1956)

2TB credit card size HD is not made by IBM (2015)

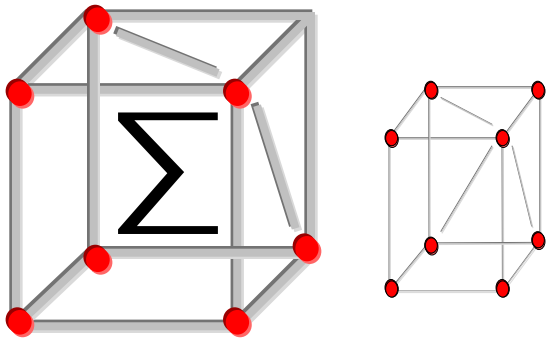
SWAPPABLE ATOMS – A DESIGN METAPHOR



A person willing to fly in the face of reason, authority, and common sense must be a person of considerable self-assurance. Since he occurs only rarely, he must seem eccentric (in at least that respect) to the rest of us. A person eccentric in one respect is often eccentric in others.

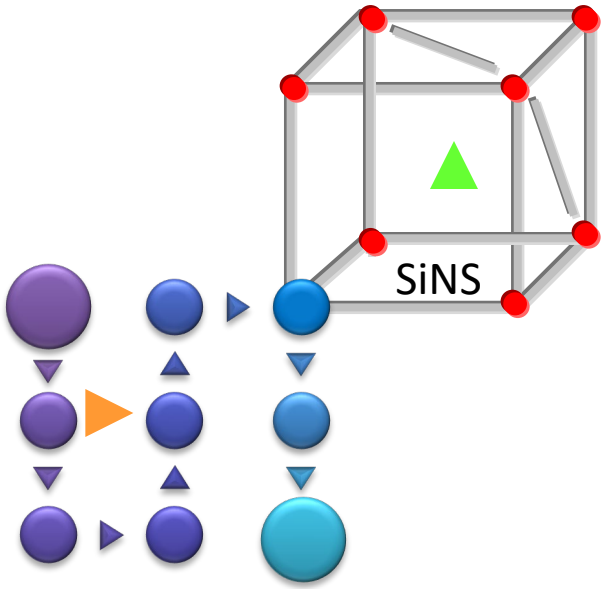
Consequently, the person who is most likely to get new ideas is a person of good background in the field of interest and one who is unconventional in his habits. (To be a crackpot is not, however, enough

ISAAC ASIMOV



ENERGY

EMERGING DISRUPTIVE SUPPLY CHAINS



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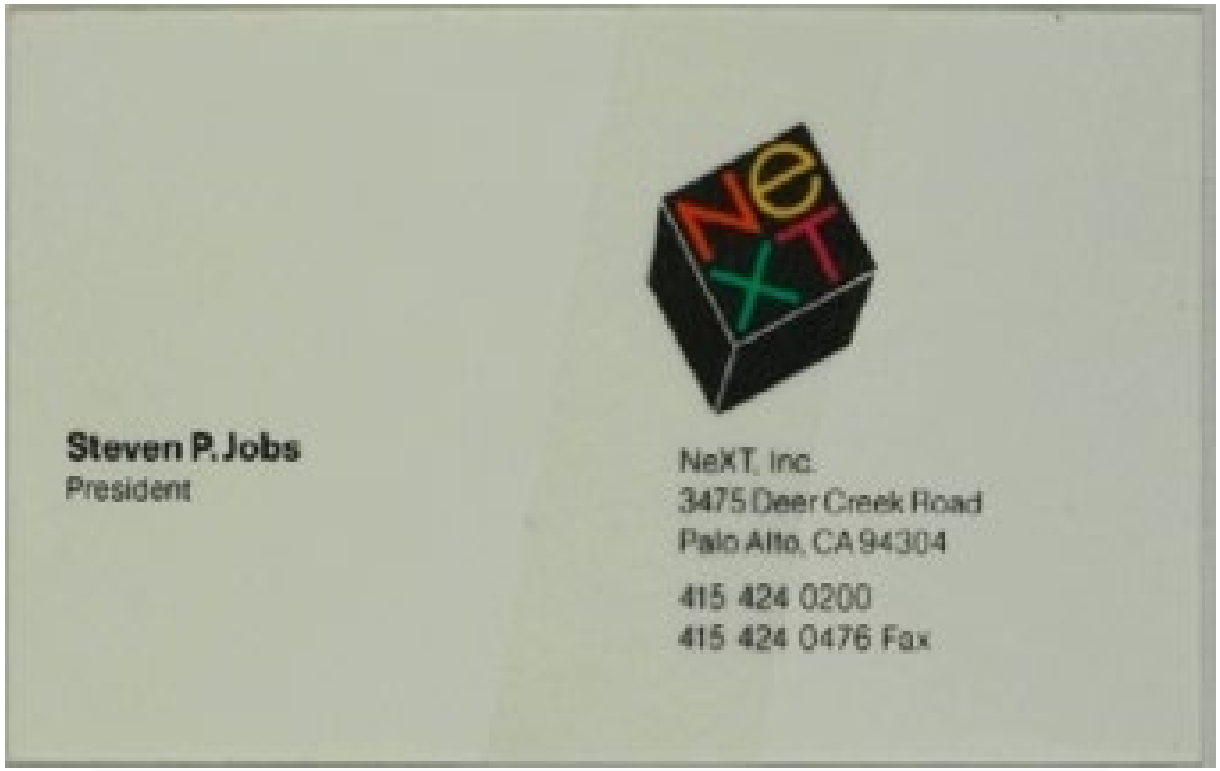
The Next Frontier

mREM

Micro-Scale
Renewable
Energy
Manufacturing

IRRELEVANT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“ A Sense of the Future ”

"So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us?
Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said,
'Hey, we don't need you. You haven't got through college yet.'" -- *Steve Jobs on attempts to get Atari and HP interested in his and Steve Wozniak's Apple PC.*

The Next Frontier

Mainframe computers to handheld iPads provides the analogy for the future of energy. Oil behemoths to renewable bio energy generators for commercial or domestic purposes using butanol or glucose. Micro-scale production and aggregation.

mREM

On April 8, 1982, while on a sabbatical at NIST (then U.S. National Bureau of Standards and Technology) in Washington, D.C., Daniel Shechtman observed crystals with 10 points - pentagonal symmetry, which most scientists said was impossible. For months he tried to persuade his colleagues but they refused to accept it. Finally he was asked to leave his research group.

"I told everyone who was ready to listen that I had material with pentagonal symmetry. People just laughed at me," Shechtman said.

Shechtman returned to Israel, where a colleague was prepared to work with him on an article describing the phenomenon. The article was first rejected but finally published in November 1984 - to an uproar in the scientific world. Two time Nobel Prize winner Linus Pauling was among those who never accepted the findings.

He (Linus Pauling) would stand on those platforms and declare, 'Danny Shechtman is talking nonsense. There is no such thing as quasicrystals, only quasi-scientists.'

http://www.physorg.com/news/2011-10-daniel-shechtman-nobel-chemistry-prize.html

Why ?

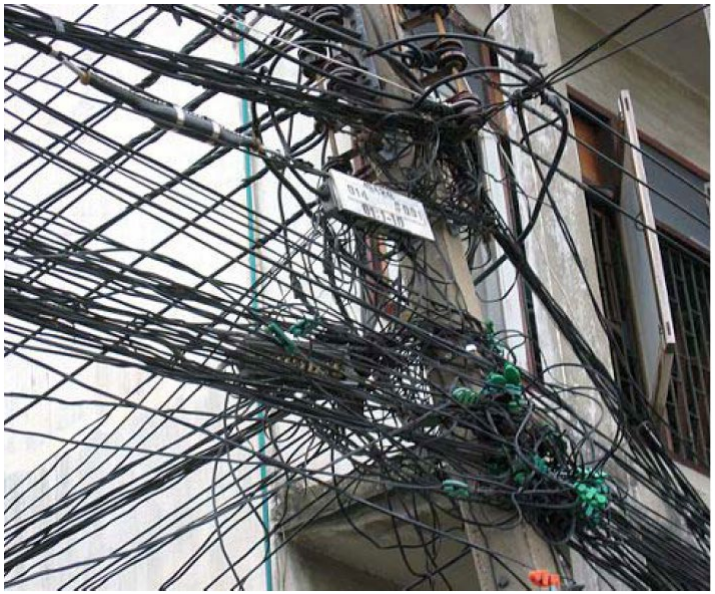
Tools to improve the quality of life and living are an index of the progress of (material) civilization. Invention and innovation of such tools seed economic growth but only with dissemination, diffusion and adoption of these tools at a granular level sufficient enough to induce paradigm shifts. Commodities such as bricks, glass, metal alloys and paper do not even register on our mind, today, because availability of these items, globally, is taken for granted. In recent times, computation has undergone a similar transformation from the ENIAC to iPad. The power of computation coupled with the decrease in price of storage media, distributed to the masses, has enabled quantum leaps of productivity and the outcome speaks for itself [1]. It has catalyzed a new era of social interaction epitomized by the 500 million subscribers Who choose to connect on a single platform (Facebook) and the services provided by companies such as Google and Baidu.

Here, I have used the "distributed" paradigm and applied it to energy. I expect comments [2] similar to that of Thomas Watson (*there is a world market for five computers*, 1943). Energy is one of the four pillars of civilization but the development of energy resources, thus far, has been restricted in the hands of a few, for justifiable reasons. Dissemination of the knowledge to manufacture non-fossil energy and adoption of the tools for domestic manufacture of liquid fuel may be analogous to making bread at home, daily, by investing to buy a Zojirushi BB or Panasonic SD breadmaker. Global economic development is held hostage by an oligopoly of fossil-based energy producers or power manufacturing systems that may not have a 'miniaturization' prospect, eg, hydroelectric. To reduce the uncertainty due to energy cost and its volatility on global economic growth, there must be alternatives to the rate-limiting steps of energy manufacturing. The future portfolio of energy may contain fission and fusion with renewable sources, eg, wind, solar and biofuels, but will the generation of power and distribution still remain an oligopoly? This proposal suggests otherwise and offers a potential for an energy agnostic global economy.

Bacterial production of liquid fuel, eg, butanol (C4) and pentanol (C5) has been proven. Bacterial can also produce glucose (C6). The scale up necessary for these non-fossil and non-vegetative liquid fuel are in progress. These activities are covered by patents and the patent owners may be the members of the oligopoly who may control the future non-fossil energy market in a manner similar to the fossil fuel cartels (OPEC). The engineering of bacteria to produce C4/C5 /C6 are based on fundamental principles of molecular biology. Hence, it is an opportunity for cooperative investment to develop liquid fuel as global public goods and aggressively replicate the process worldwide to provide a non-fossil, non-vegetative, carbon neutral energy alternative. It is not a panacea but one solution which can be used in a domestic capacity as well as industrial and potentially for large-scale energy manufacturing distributed over the future smart grid.

Domestication and self-sufficiency of energy which does not add to the global concern regarding green house gas (GHG) emissions makes economic sense for catalyzing global growth and makes a direct contribution to worldwide sustainability. This proposal achieves this lofty goal. It seeks investment to transform this vision to reality by those who may choose to act as global benefactors but without sacrificing their capital ***and*** earn a decent return on their investment (ROI). The potential for profitability from the global manufacturing nd sale of liquid fuel may be only limited by our imagination. The investors will make it possible for the energy-starved nations to ramp up production by reducing the barrier to access technology. Hence, only those investors are invited who may invest not only for a ROI but also to serve as purveyors of civilization.

[1] http://www.boston.com/business/articles/2011/01/31/despite_chinas_threat_us_production_still_no_1/
[2] http://www.rinkworks.com/said/predictions.shtml



FUTURE FOR NON-FOSSIL LIQUID FUEL?

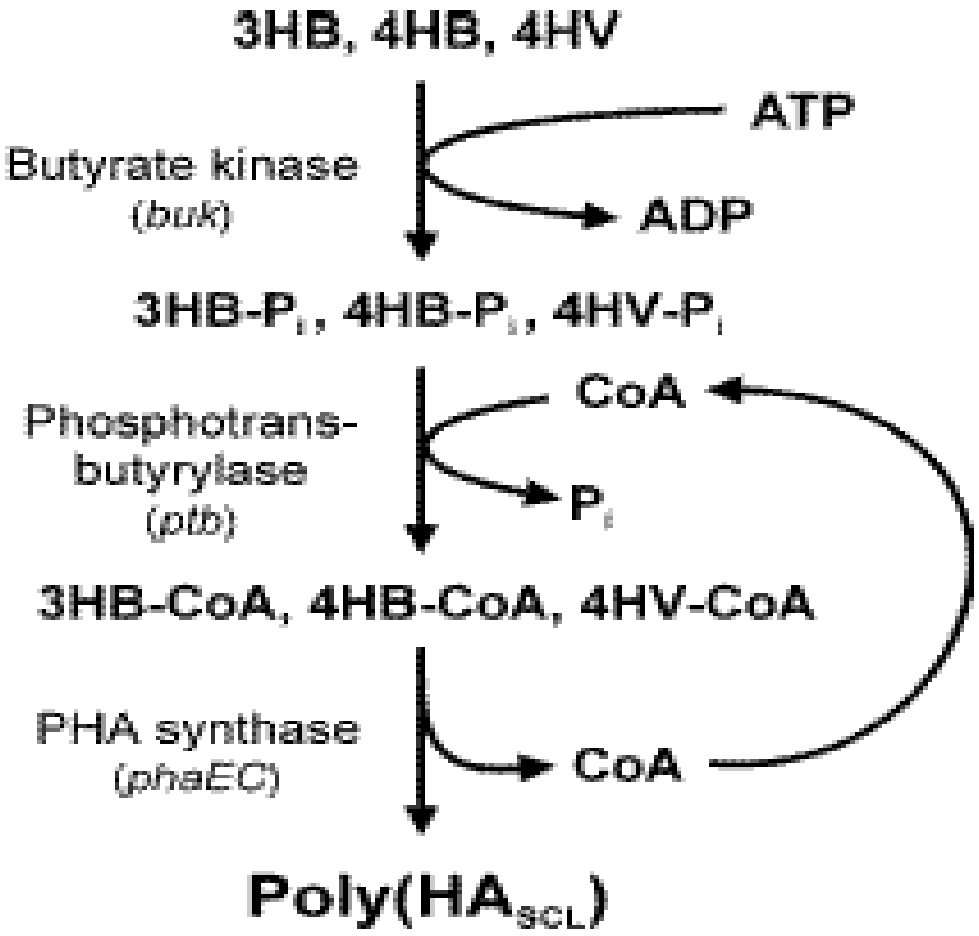
Renewable Innovation

Metabolic Engineering

Non-natural biosynthesis

Polyhydroxyalkanoic acid

Prokaryotic carbon store



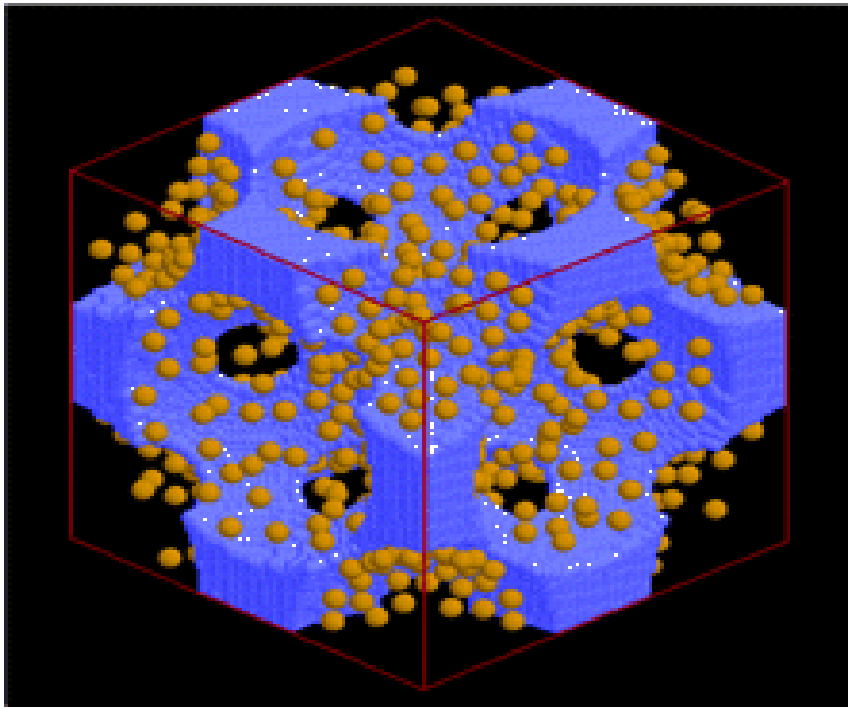
Steinbuchel, 2003. Biochemical Eng J 16 81-96

Before Hydrogen - Methanol & Natural Gas

- **Fischer-Tropsch Process**
- **Methanol Economy**
- **George Olah, Nobel Prize in Chemistry**

NanoLetters (2004) 4 1489-1492

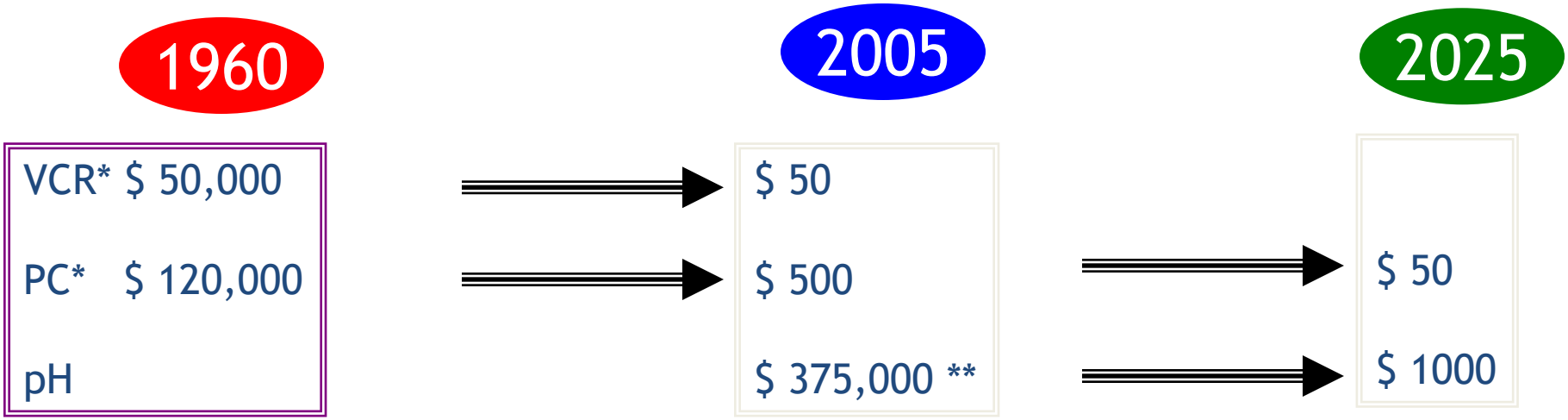
Hydrogen



Molecular Simulation of Novel Carbonaceous Materials for Hydrogen Storage

Hydrogen molecules adsorbed in the GCIO porous material. Carbonaceous material indicated in blue and yellow spheres represent Hydrogen.

Portable Hydrogen Plant [pH] in Every Garage



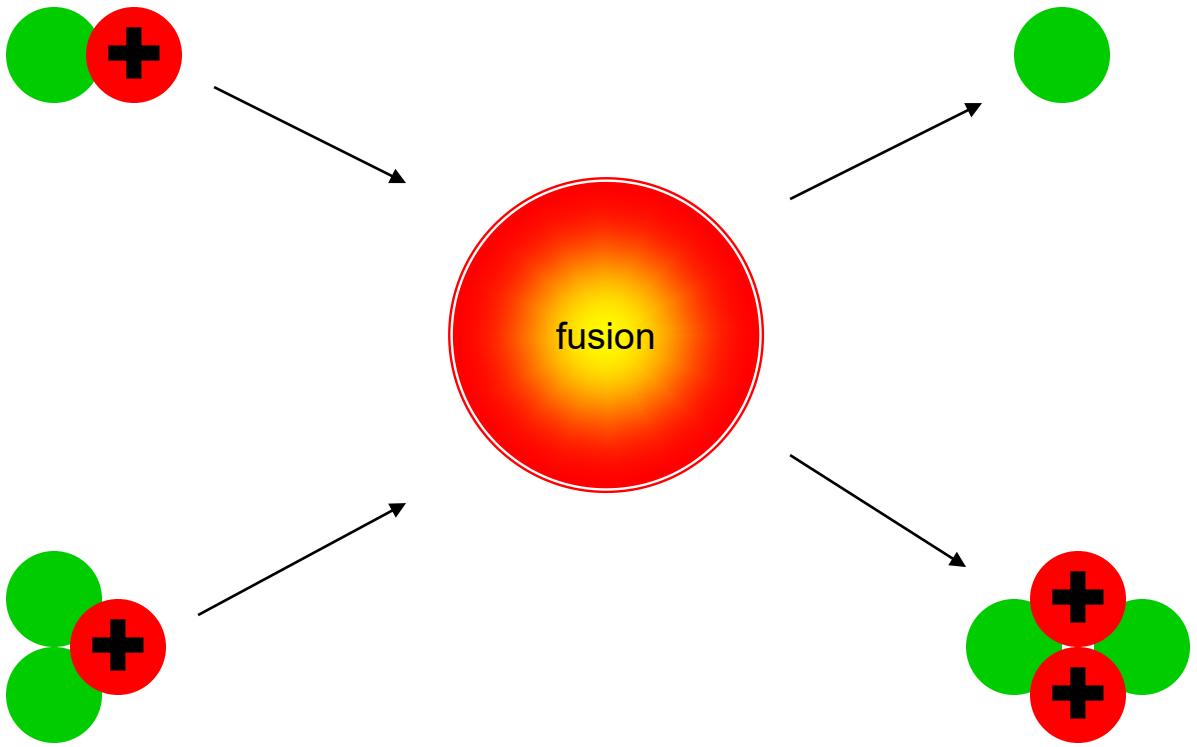
**Cost of semi-portable Hydrogen generator from natural gas (www.auto.com/industry/hfuel5_20030305.htm)

* VCR manufactured by AMPEX Corporation; *Desktop PC model PDP-1 manufactured by DEC

A chicken in every pot and a car in every garage!

Herbert Hoover 1928 (1929-1933) 31st POTUS

After Hydrogen: Fusion



- **Energy in your cupboard**

Liquid Fuel

Think Different

LIQUID FUTURE by S. Datta

FUTURE Post-2100

Chloroplast nano-chip

Non-sugar synthesis

DE NOVO

CORN

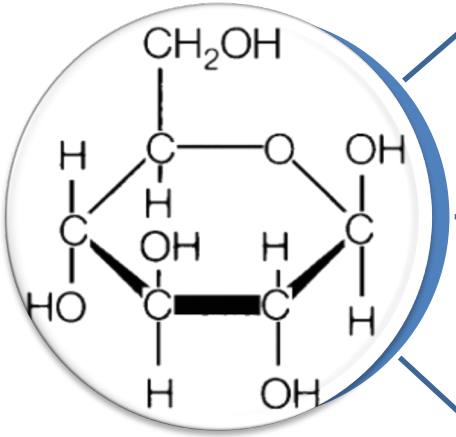
PLANT GROWTH

COSKATA

WASTE CARBON

Bacteria, Algae

PHOTO



Butanol

- Prather 2009
- Atsumi 2008

Pentanol

Ethanol

- Stephanopoulos 2006

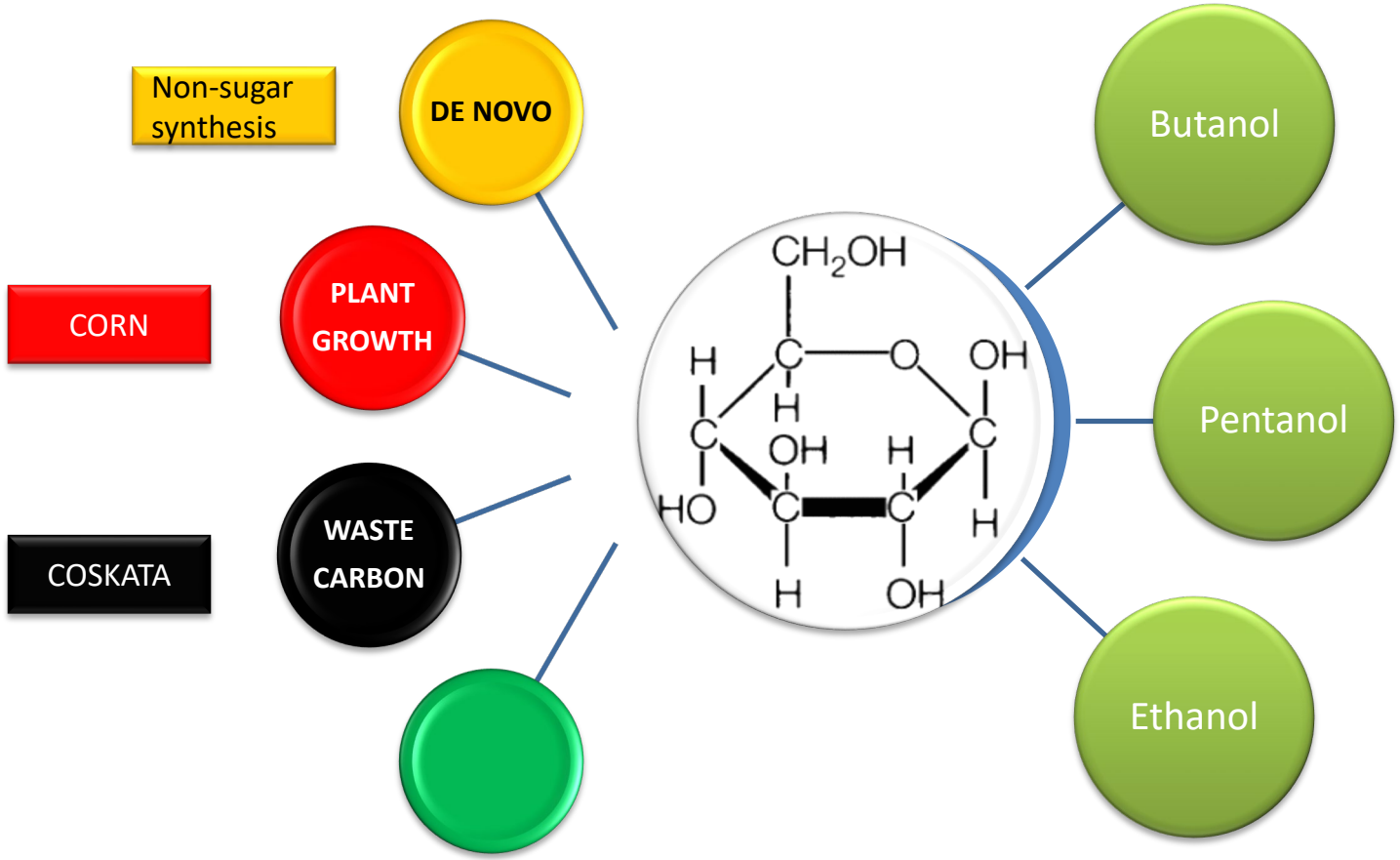
Immobile Enzymes

Home Butanol Generator

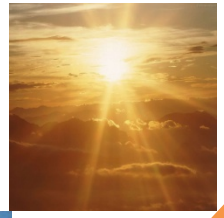
In the post-2050 era, energy from nuclear fission and fusion may predominate grid based power but if liquid fuel demand still exists, it may catapult glucose manufacturing as a new LOB for small and medium enterprises. High insolation zones may directly produce C4-C5 liquid fuel as well as glucose.

The World Is Not Flat – One Shoe Does Not Fit All

Glucose as a Commodity for Liquid Fuel Supply Chain
Is Glucose an intermediary in low insolation zones?



Photosynthetic Butanol Production in High Insolation Zones



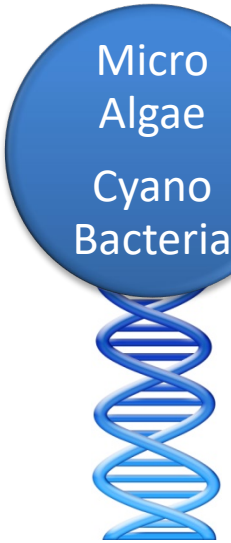
C 4
C 5

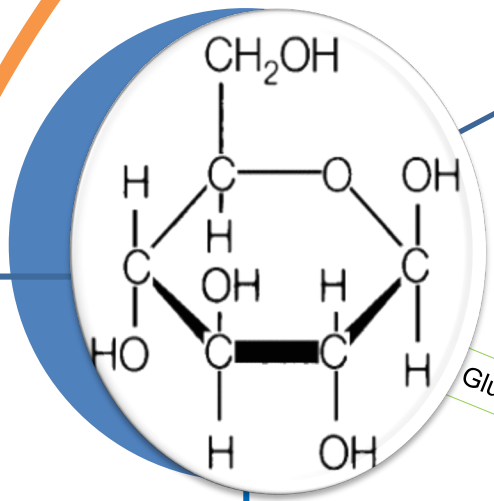
Butanol
Pentanol

Low Insolation Commodity

Micro Algae

Cyano Bacteria





Glucose

C 6

Glucose Commodity

Butanol Generator

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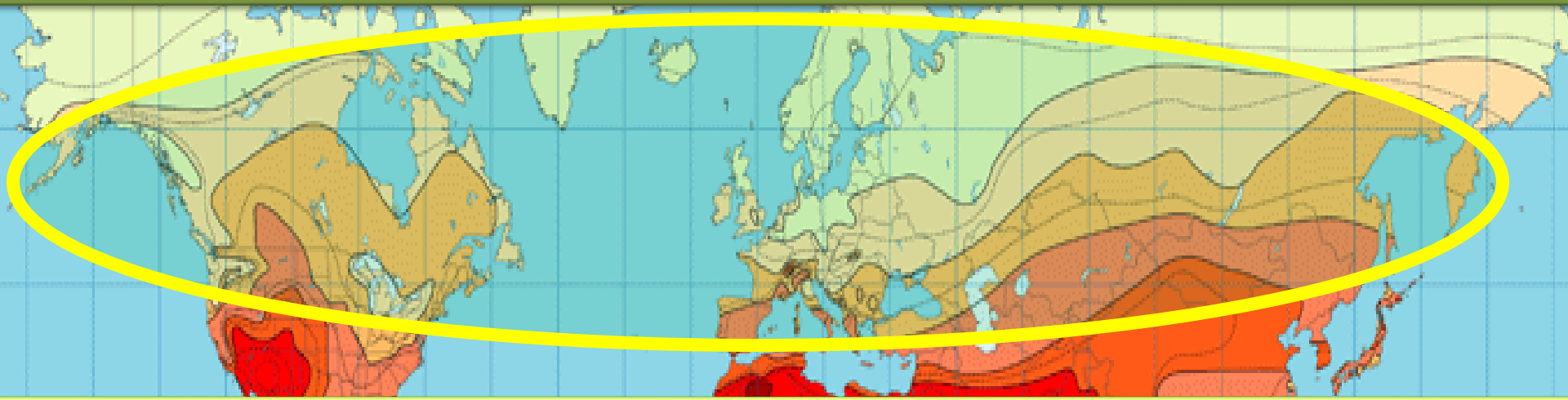


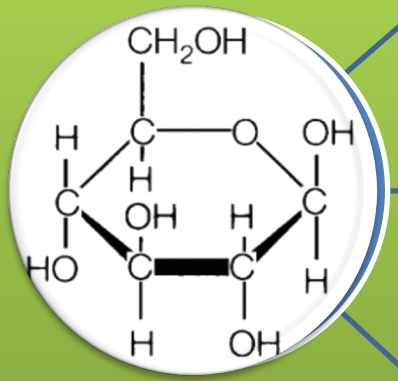
DE NOVO

CORN

PLANT GROWTH

COSKATA

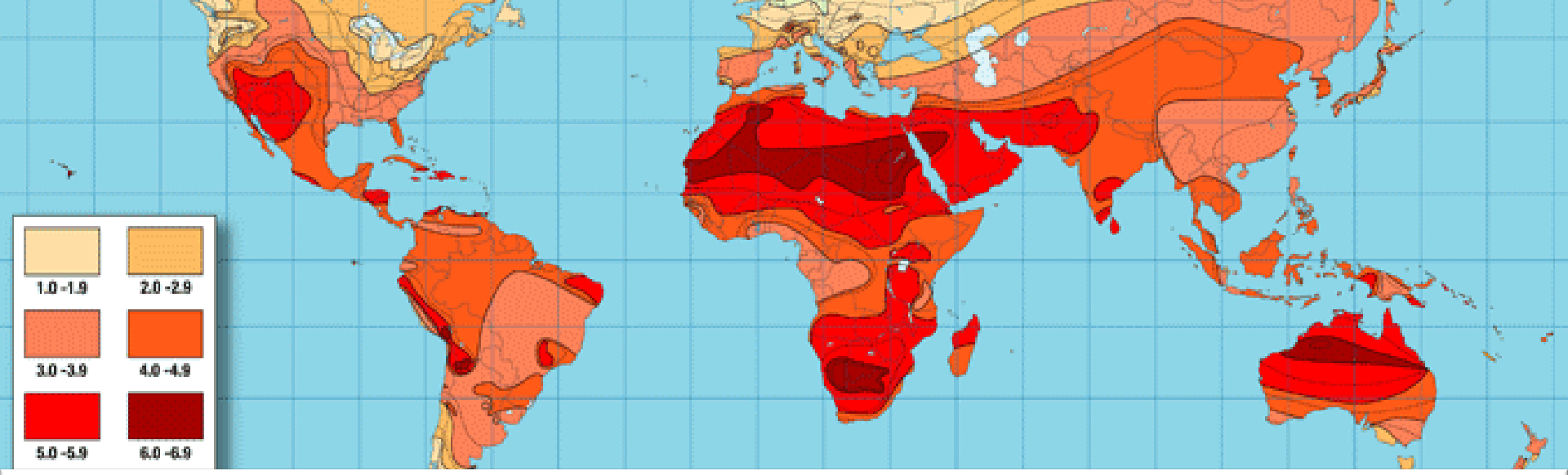
WASTE CARBON



Butanol

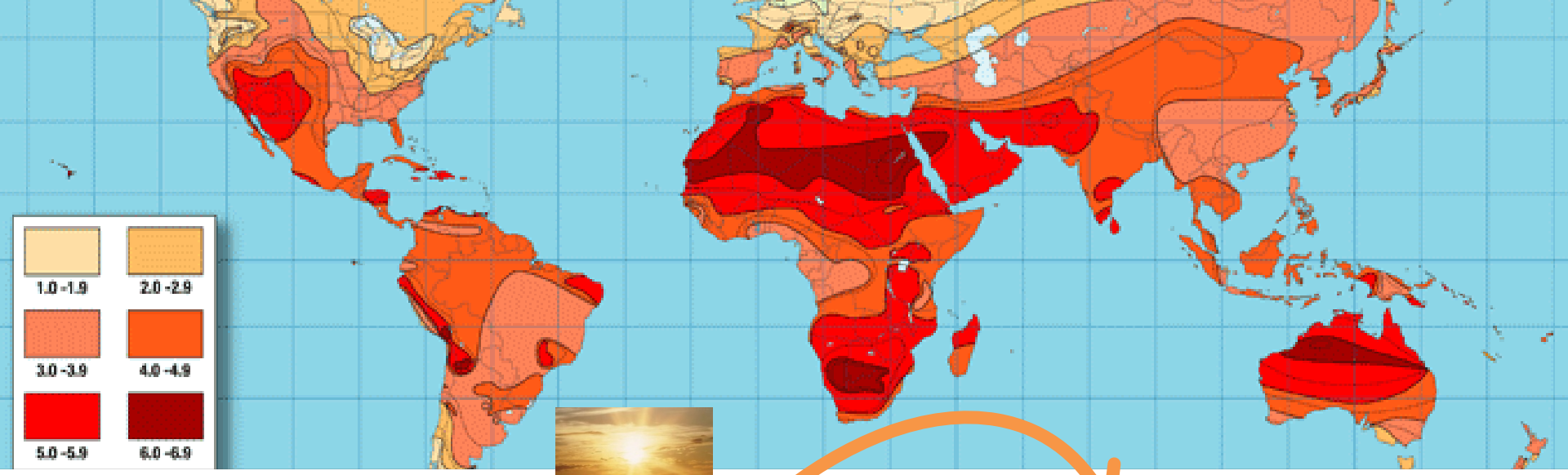
Pentanol

Ethanol



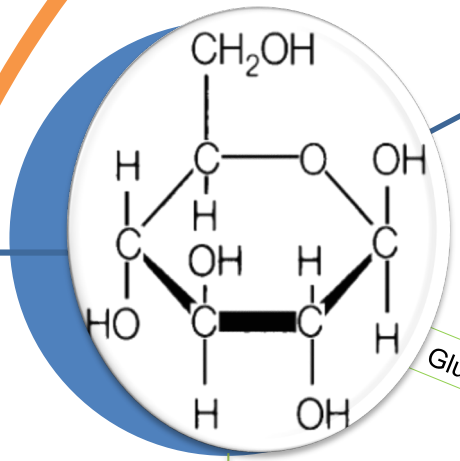
High Insolation Zones

THE SAHARA BATTERY COMPANY



Micro Algae

Cyano Bacteria



Glucose

Liquid Fuel Generator

C 4
C 5

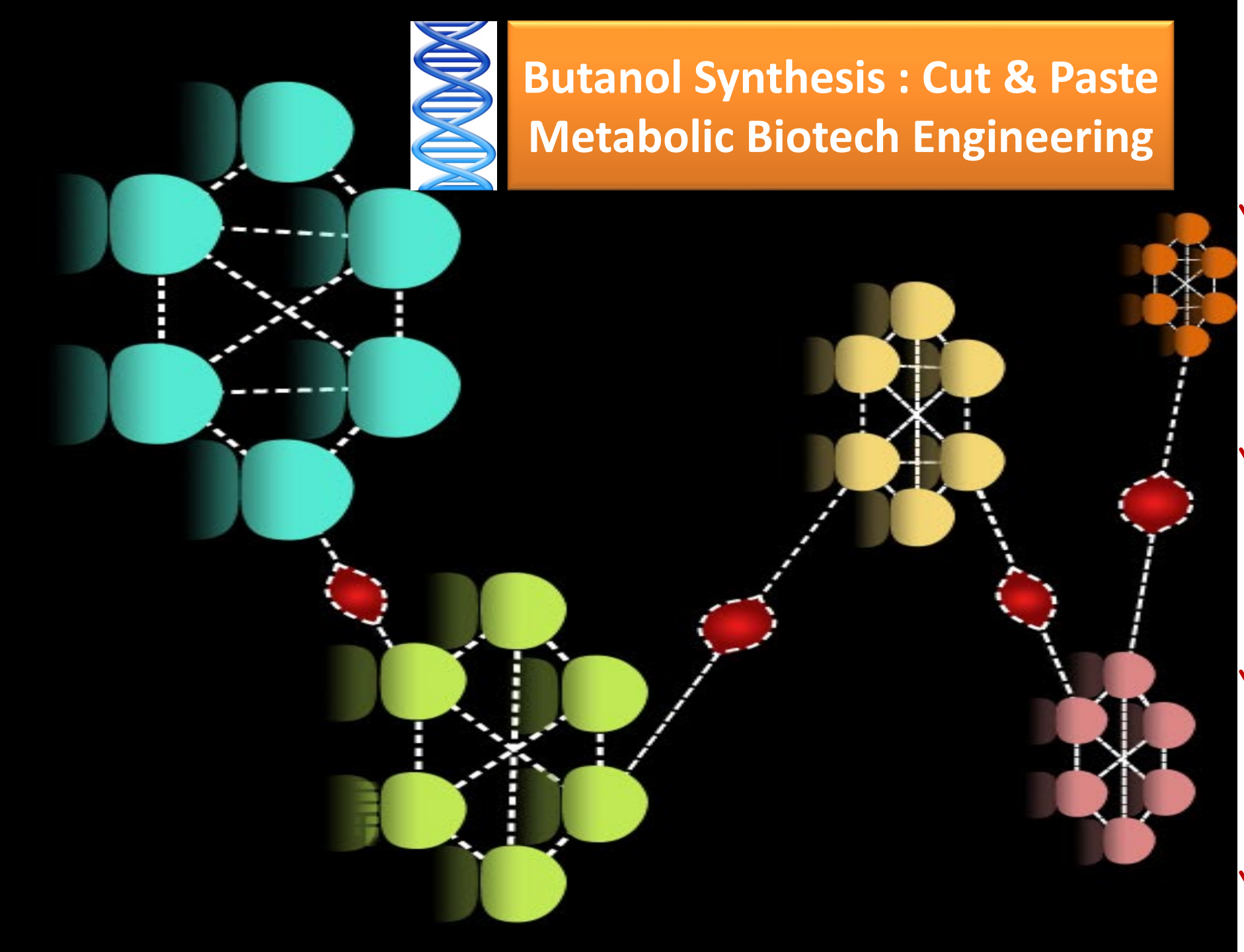
Butanol
Pentanol

Low Insolation Commodity

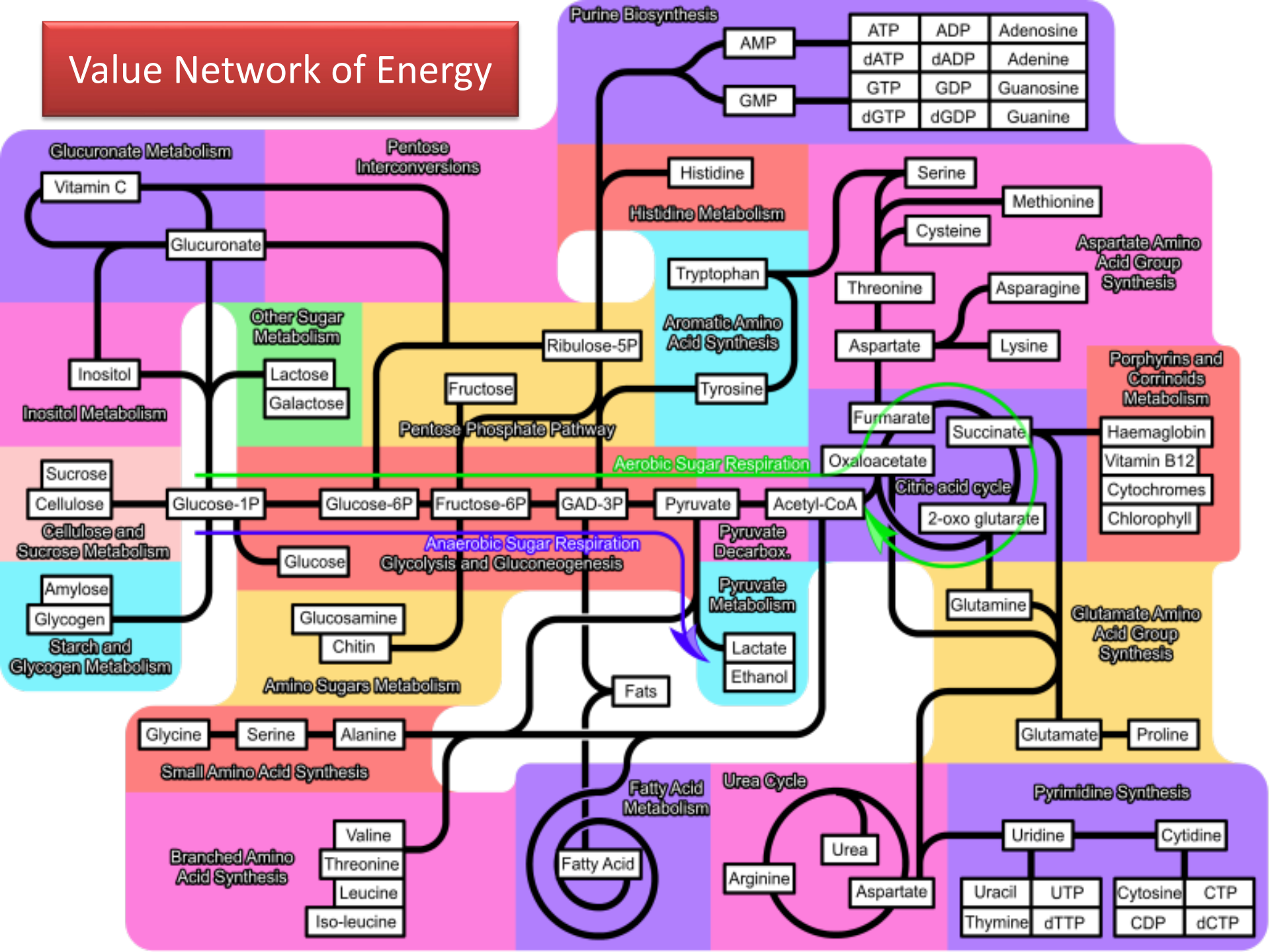
C 6

Glucose

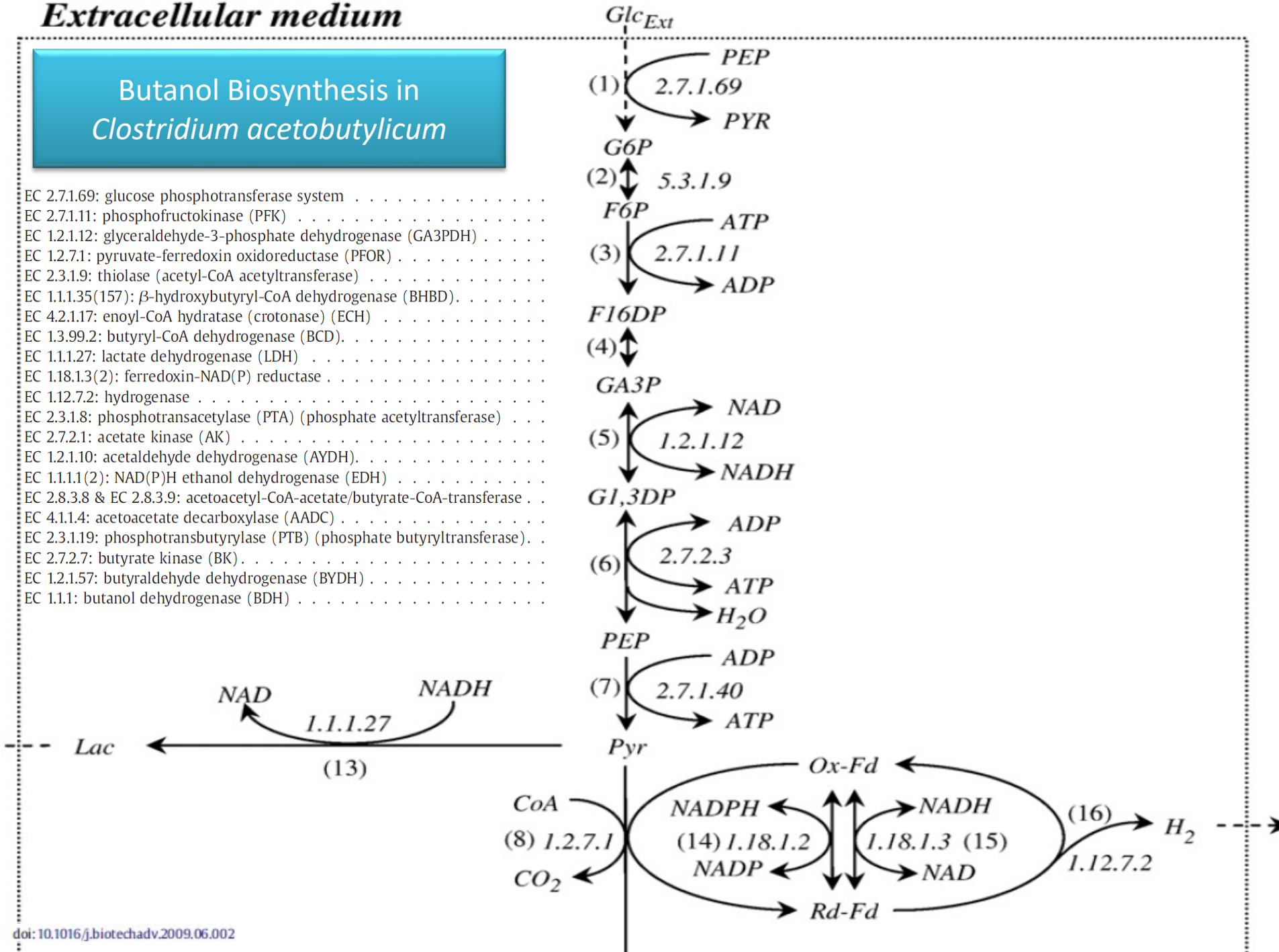
Butanol Synthesis : Cut & Paste Metabolic Biotech Engineering



Value Network of Energy



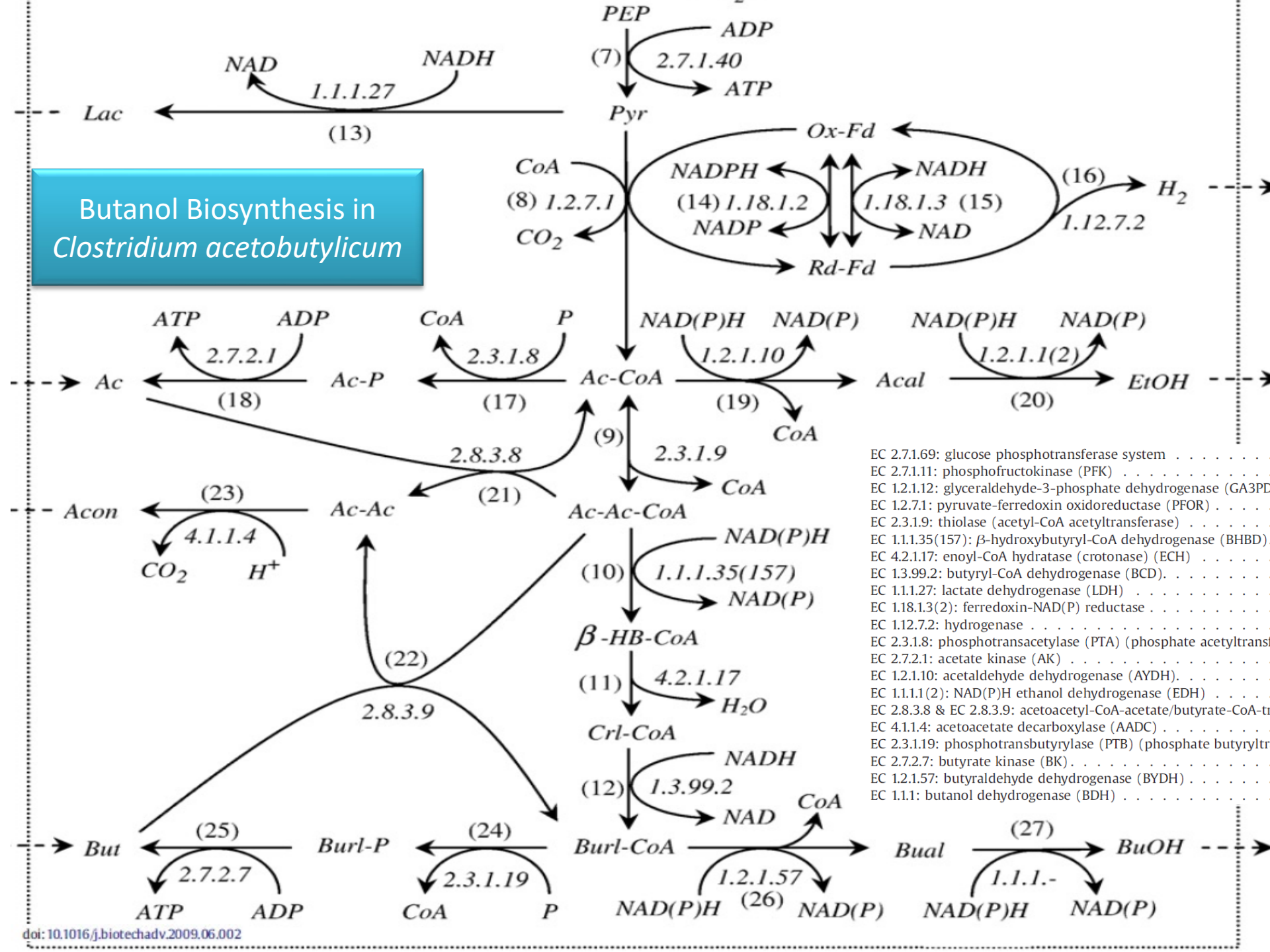
Butanol Biosynthesis in *Clostridium acetobutylicum*



EC 2.7.1.69: glucose phosphotransferase system
EC 2.7.1.11: phosphofructokinase (PFK)
EC 1.2.1.12: glyceraldehyde-3-phosphate dehydrogenase (GA3PDH)
EC 1.2.7.1: pyruvate-ferredoxin oxidoreductase (PFOR)
EC 2.3.1.9: thiolase (acetyl-CoA acetyltransferase)
EC 1.1.1.35(157): β-hydroxybutyryl-CoA dehydrogenase (BHBD)
EC 4.2.1.17: enoyl-CoA hydratase (crotonase) (ECH)
EC 1.3.99.2: butyryl-CoA dehydrogenase (BCD)
EC 1.1.1.27: lactate dehydrogenase (LDH)
EC 1.18.1.3(2): ferredoxin-NAD(P) reductase
EC 1.12.7.2: hydrogenase
EC 2.3.1.8: phosphotransacetylase (PTA) (phosphate acetyltransferase)
EC 2.7.2.1: acetate kinase (AK)
EC 1.2.1.10: acetaldehyde dehydrogenase (AYDH)
EC 1.1.1.1(2): NAD(P)H ethanol dehydrogenase (EDH)
EC 2.8.3.8 & EC 2.8.3.9: acetoacetyl-CoA-acetate/butyrate-CoA-transferase
EC 4.1.1.4: acetoacetate decarboxylase (AADC)
EC 2.3.1.19: phosphotransbutyrylase (PTB) (phosphate butyryltransferase)
EC 2.7.2.7: butyrate kinase (BK)
EC 1.2.1.57: butyraldehyde dehydrogenase (BYDH)
EC 1.1.1: butanol dehydrogenase (BDH)

doi: 10.1016/j.biotechadv.2009.06.002

Butanol Biosynthesis in *Clostridium acetobutylicum*



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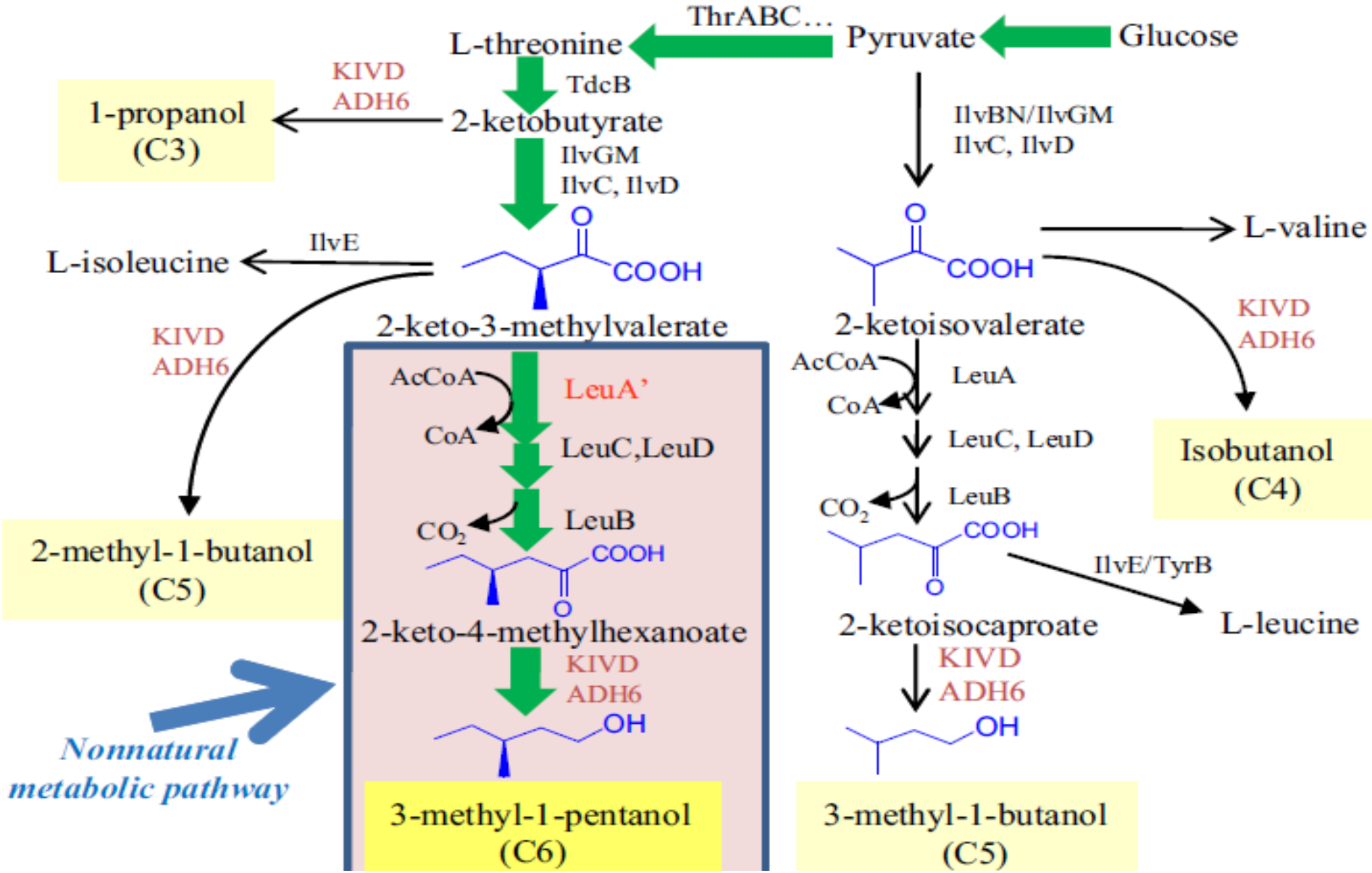
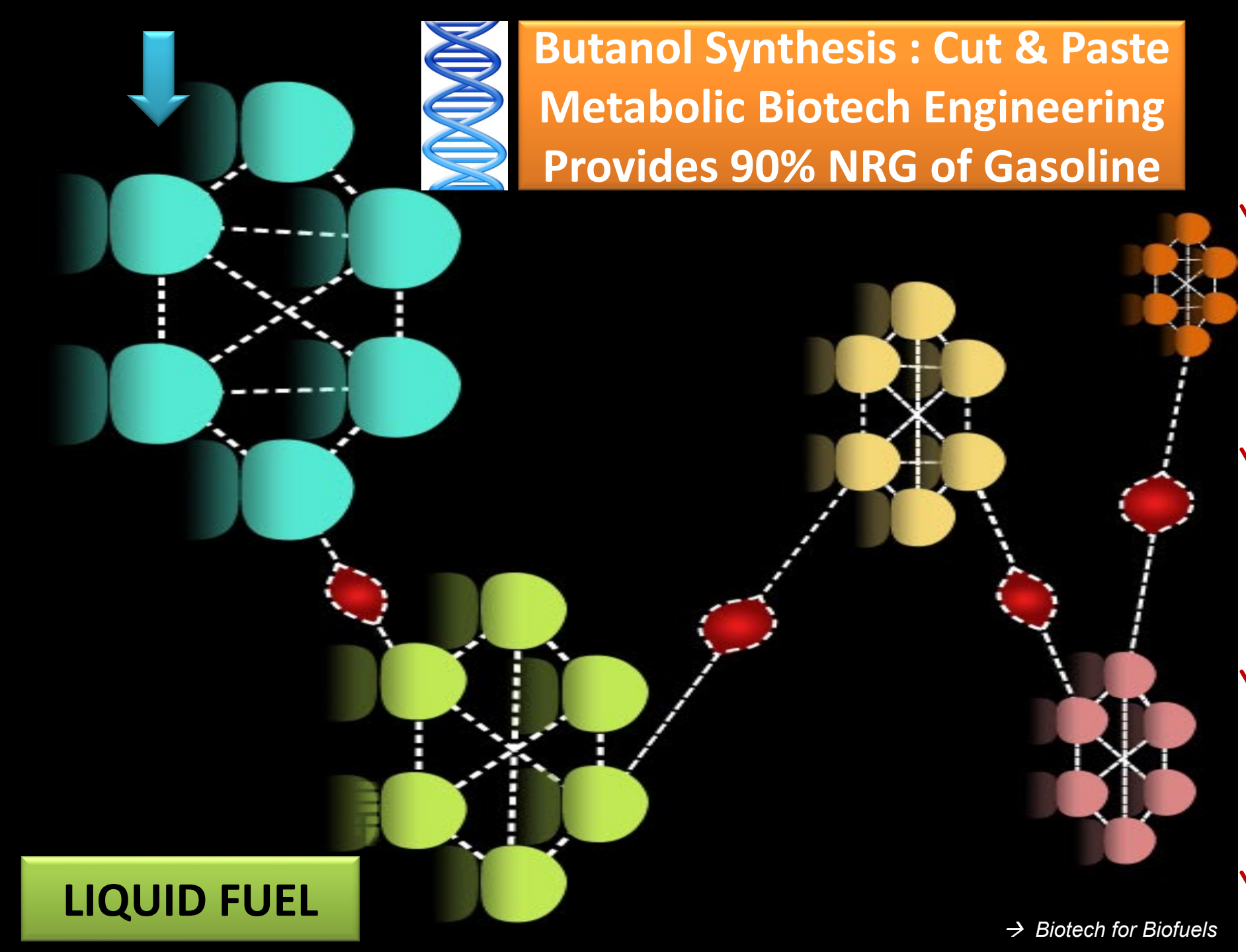
Energy Supply Chain: Metabolic Engineering of Supply Network Planning



www.pnas.org/content/suppl/2008/12/08/0807157106.DCSupplemental/0807157106SI.pdf


Butanol Synthesis : Cut & Paste
Metabolic Biotech Engineering
Provides 90% NRG of Gasoline
LIQUID FUEL
→ Biotech for Biofuels

FUTURE
Post-2100

Chloroplast
nano-chip

Non-sugar
Synthesis

DE NOVO

CORN

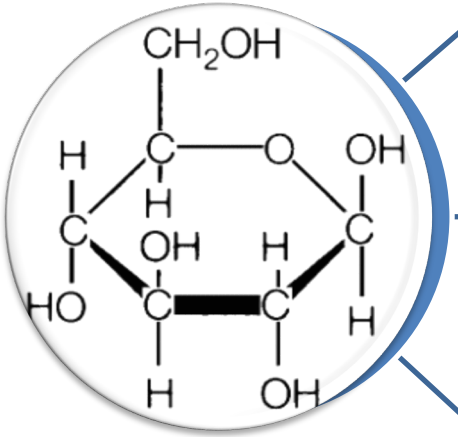
PLANT
GROWTH

COSKATA

WASTE
CARBON

Bacteria
Algae

PHOTO



Butanol

Pentanol

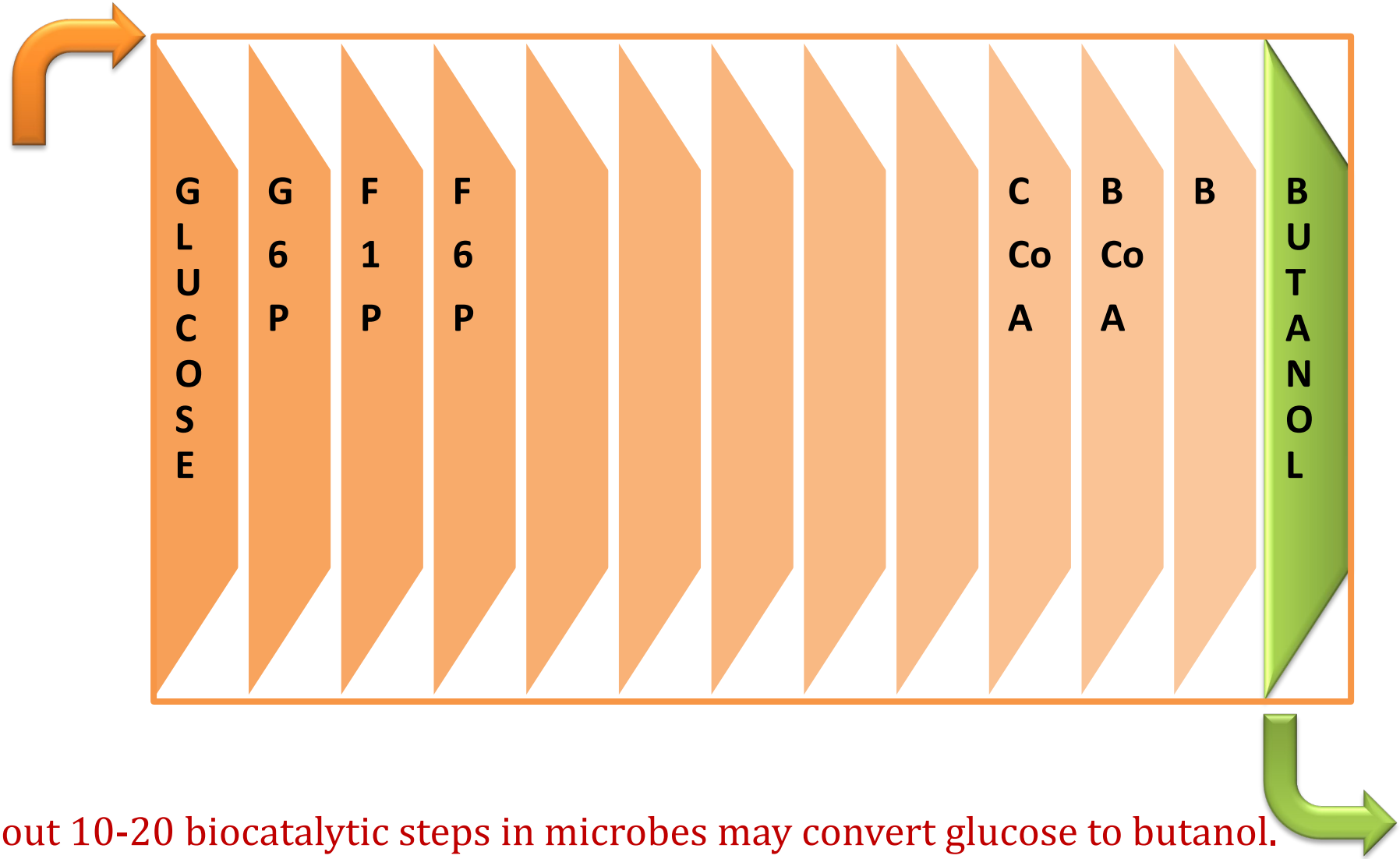
Ethanol

Personal
Electricity
Generator

Immobile
Enzymes

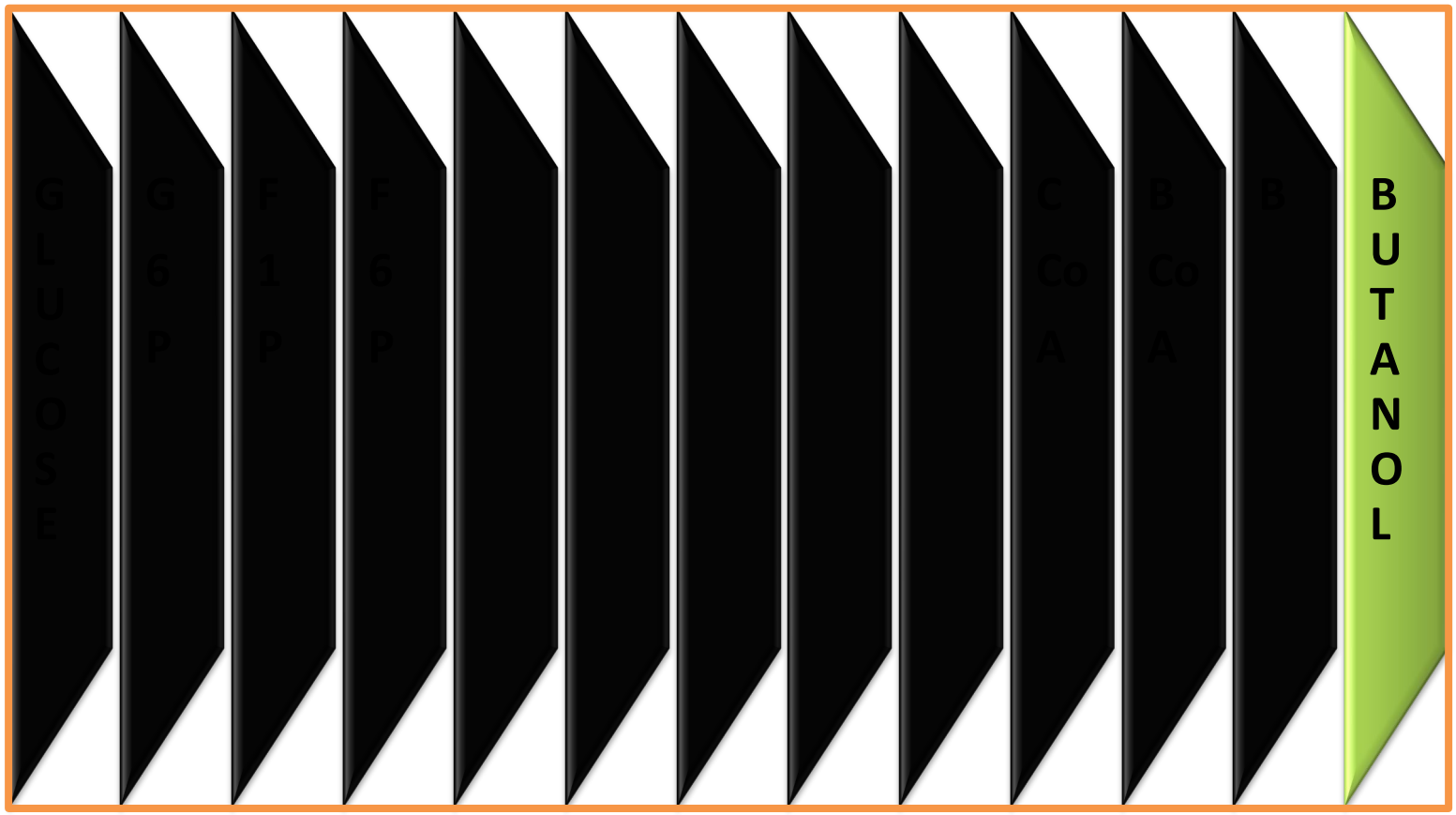
Home Butanol
Generator

Hypothetical Immobilized Enzymatic Catalysis of Glucose to Butanol
Butanol Battery 2020



About 10-20 biocatalytic steps in microbes may convert glucose to butanol. These enzymes immobilized on substrates may form a multi-layer cube. If functional, the cascade may convert glucose (commodity) directly to butanol.

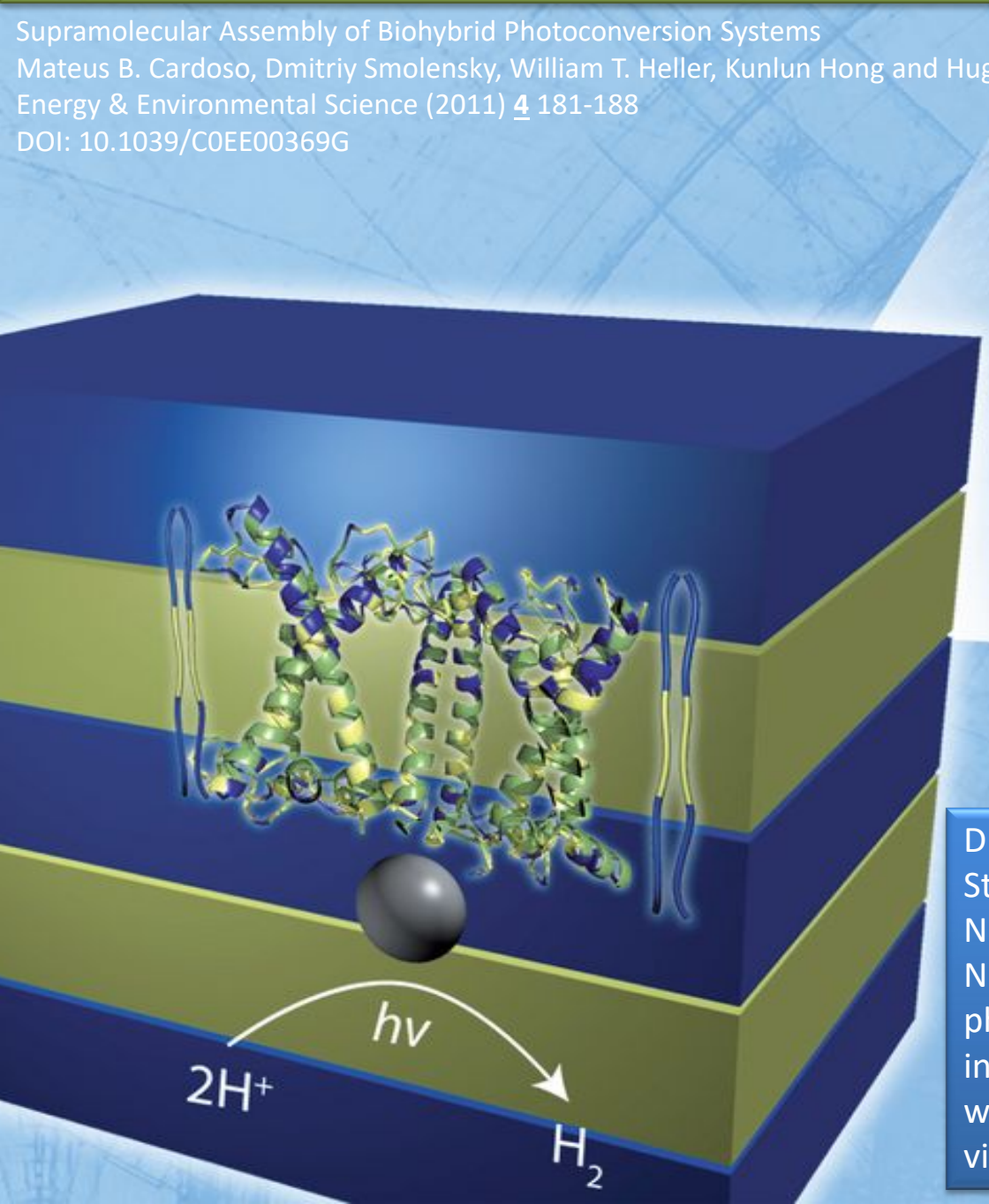
Hypothetical Immobilized Enzymatic Catalysis in Nano-Chloroplasts 2100 AD

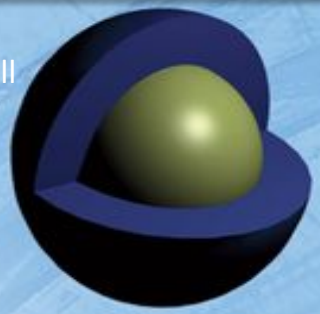


Light-dependent (photosystem I and II) and light-independent reactions of photosynthesis may be difficult (but not impossible) to functionalize *(as above)* due to the vast number of integral proteins in thylakoids in chloroplasts.

Hypothetical Immobilized Enzymatic Catalysis in Nano-Chloroplasts ?

Supramolecular Assembly of Biohybrid Photoconversion Systems
Mateus B. Cardoso, Dmitriy Smolensky, William T. Heller, Kunlun Hong and Hugh O'Neill
Energy & Environmental Science (2011) **4** 181-188
DOI: 10.1039/C0EE00369G





Dr Hugh O'Neill *et al* at the ORNL Center for Structural Molecular Biology and Center for Nanophase Materials Sciences (Oak Ridge National Lab) have developed a bio-hybrid photo-conversion system based on the interaction of photo-synthetic plant proteins with synthetic polymers which can convert visible light into hydrogen fuel.

Based on proven gross inefficiencies of the internal combustion engine in converting chemical energy to mechanical energy (about 15%) it is clear that the future is electric. Then, why pursue scaling production of liquid fuel (C4, C5) from bacteria?

The answer is not simple but at least one simple answer is that predictions are difficult, especially when the question at hand requires one to forecast when rapid-charge car batteries will commence mass production. Reducing the re-charge time from 30-60 minutes to 5-10 minutes may be the disruptive factor that catalyzes or inhibits mass adoption of electric vehicles.

Action Plan

Progressive Entrepreneurial Innovation
Yes, we can!

- Connect with or create collaborative infrastructure (laboratory)
- Source or develop fuel generating microorganism
- Adapt or re-tool photo-bioreactor
- Produce butanol and establish metrics
- END OF PRE-PHASE (intellectual property)
- START OF PHASE 1 – scale to 1 L / hr
- Phase 1a – small scale reactor (new product)
- START OF PHASE 2 – scale to 10 L / hr
- Phase 2b – medium scale reactor (product)
- Net energy vs insolation analysis / optimize
- START OF PHASE 3 – scale to 100 L / hr
- Phase 3b – large scale reactor (plant)
- Local and global production/distribution
- Significant new job creation / grow economy
- Fossil fuel independence reduces GHG

Risk Averse Cautious Analysis and Study
Why we cannot …

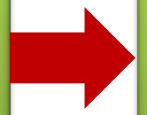
- There are at least five famous groups who have patents on fuel producing bacteria.
- Producing bio-tech butanol is not new.
- Photo-bioreactor re-engineering requires chemical and mechanical engineers.
- May need 1-2 years to arrive at Phase 1.
- Uncertainty and risk in scalability estimates.
- 2 million dollars over 2-3 years is too much.
- This is different from our mandate / remit.
- ROI will take 2-5 years and that is too long.
- Who will hire the experts and the students?
- Who will manage this complex project?
- We will wait for universities to do the work.
- We don't want any genetic engineering.
- Corn ethanol will suffice as the liquid fuel .
- We have enough fossil fuel for 150 years !

Short Term Focus for Scalable Photo-Production of Liquid

C4

Demonstrate

- Bench-top reactor
- 1 liter per hour
- 1-2 years



- Garden reactor
- 10 liters per hour
- 2-3 years

Current Oil use ~16 billion L / day

Scenario - Photo bio-reactor scalability plateau - 10 L / hour

Global C4 Demand Doubles to 10 trillion L / yr

Single Unit Production

- 10 L / hour
- 50% efficiency
- 50% insolation
- Yield ~ 20,000 L / yr

Distributed Production

- 500 million users
- Garden reactor
- 500 million products
- Yield 10 trillion L / yr

The Cautious

- I don’t want fuel in my house
- My GM Volt uses A123 battery
- I don’t want to buy these products - we have the grid
- Really what does this achieve?
- Is this sustainable?
- There are other solutions.
- What about electricity from sewer sludge?
- Is there a market for this product?

The Optimist

- Animal Farm, Server Farms and now C4-ward Farms at remote locations.
- Generator converts C4 to electricity and feeds GM Volt or sell to the grid.
- Utilities can also own C4-ward Farms as the source of electricity to the grid.
- Independence from fossil fuels using non-vegetative (not food) source.
- It is sustainable and carbon neutral which helps stabilize/reduce GHG.
- C4 is not a panacea but when combined with C6 offers a global solution which uses C6 as a non-perishable, non-exhaustible commodity for the supply chain of energy agnostic global economy.
- Good idea from Craig Venter but do you want sewer sludge in your house?
- Sales over 10-20 years for 500 million units at $1,000 per unit = $500 billion. Maintenance micro-payment at 50 c per day = $90 billion pa for services.

Temporary Questions ?

Is it feasible to partially reduce GHG emissions by manufacturing vegetation-independent non-fossil carbon-neutral C4-C5 renewable liquid fuel from cyano-bacteria (micro-algae) using sunlight and carbon dioxide?

The risk in this manufacturing process is scalability of production volume to make a sufficient contribution as fuel source for global use. The risk may also be a reward. If cost or technology for scalability is unsuitable then production volume may remain low. The low volume product may be suitable and affordable for domestic use or small businesses. If each home or small business owned its independent energy manufacturing appliance (liquid fuel generator), it may reduce demand for grid distributed power. 80% of the global population benefits even from low volume.

Fuel (C4, C5) produced in high insolation zones will be useful locally but transportation is costly. Hence, the emergence of glucose (C6) as a driver of the future liquid energy supply chain. High insolation zones in developing nations can produce C6 and sell the product to industrialized nations in low insolation zones. Glucose may be converted by a variety of microbial or other methods to C4,C5 fuels without sunlight or the need to source vegetation or waste. Inventory of glucose may provide nations with energy security and partially reduce the uncertainty from energy prices which triggers volatility in economic development and socio-economic stability.

Production of C6 from embedded photosynthetic enzymatic components immobilized on chips is a possible extension of the convergence of bio and nano-technology for renewable energy. In a manner similar to present-day solar panels, 22nd Century may expect “nano-chloroplast” panels for manufacturing glucose-on-a-chip or C4/C5 chips. The latter harnesses solar energy in chemical bonds and used on demand rather than directly generating electricity from photo-voltaic cells where energy may rapidly perish, if unused (unless storage technology significantly improves). In the interim, glucose from microbes may become an important energy commodity.

Anastomosis of sunlight-dependent C4 production with sunlight-agnostic production of C5

Renewable liquid butanol (C4) can be produced by micro-organisms using energy from sunlight and carbon dioxide from air. Because sunlight is not sufficiently available in parts of the world, butanol can be made in the ABSENCE OF SUNLIGHT if microorganisms are supplied with another source of primary energy, for example, glucose. At present many good sources of glucose are from food items (sugar cane, corn). It has ignited the food v fuel debate due to increasing cost of food items. We can avoid depleting food sources for glucose. Instead of food we can use cyano-bacteria which can directly (auto-trophic) produce glucose from sunlight & atmospheric carbon dioxide. Thus, glucose may be viewed as a cash crop and commodity which can create new lines of global business and serve as a novel ingredient in the emerging supply chain of micro-scale renewable energy manufacturing futures. Any country with sufficient sunlight can manufacture glucose. Glucose can be used in the ABSENCE OF SUNLIGHT by other micro-organisms which can use glucose as the primary energy source (and carbon dioxide from air) to produce butanol in an appliance which may function indoors. Hence, butanol can be produced WITHOUT DEPLETING FOOD sources and is agnostic of sunlight (insolation independent). The anastomosis of sunlight-dependent glucose production (as a new commodity in the energy supply chain) with sunlight-agnostic production of butanol may usher microscale energy manufacturing platform as a tool for global economic development and job growth. http://dspace.mit.edu/handle/1721.1/59804

“I cannot believe that it ever make economic sense for an individual to make the capital expenditure for his own electric generation unless that individual cannot connect to the grid. Thus I do not believe in the assumptions about the future that your paper is based upon.” – *Bob Curl 11/10/2010*

"Where a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and weigh only 1.5 tons." -- *Popular Mechanics, 1949*

"I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year." -- *The editor in charge of business books for Prentice Hall, 1957.*

"But what...is it good for?" -- *Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.*

"There is no reason anyone would want a computer in their home." -- *Ken Olson, president, chairman and founder of Digital Equipment Corp., 1977.*

"This 'telephone' has too many shortcomings to be considered as a means of communication. The device is inherently of no value.“ - *Western Union 1876.*

"The Americans have need of the telephone, but we do not. We have plenty of messenger boys." -- *Sir William Preece, chief engineer of the British Post, 1876.*

"The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?" -- *David Sarnoff's associates in response to his urgings for investment in the radio in the 1920s.*

"While theoretically and technically television may be feasible, commercially and financially it is an impossibility." -- *Lee DeForest, inventor.*

"The concept is interesting and well-formed, but in order to earn better than a 'C', the idea must be feasible." -- *A Yale University management professor in response to Fred Smith's paper proposing reliable overnight delivery service. (Smith went on to found Federal Express Corp.)*

"Who the hell wants to hear actors talk?" -- *H. M. Warner, Warner Brothers, 1927.*

"I'm just glad it'll be Clark Gable who's falling on his face and not Gary Cooper." -- *Gary Cooper on his decision not to take the role in "Gone With the Wind."*

"A cookie store is a bad idea. Besides, the market research reports say America likes crispy cookies, not soft and chewy cookies like you make." -- *Response to Debbi Fields' idea of starting Mrs. Fields' Cookies.*

"We don't like their sound, and guitar music is on the way out." -- *Decca Recording Co. rejecting the Beatles, 1962.*

"Radio has no future. Heavier-than-air flying machines are impossible. X-rays will prove to be a hoax." -- *William Thomson, Lord Kelvin, British scientist, 1899.*

"So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.'" -- *Steve Jobs on attempts to get Atari and HP interested in his and Steve Wozniak's PC.*

"If I had thought about it, I wouldn't have done the experiment. The literature was full of examples that said you can't do this." -- *Spencer Silver on the work that led to the unique adhesives for 3-M "Post-It" Notepads.*

"It will be years -- not in my time -- before a woman will become Prime Minister." -- *Margaret Thatcher, 1974.*

"I see no good reasons why the views given in this volume should shock the religious sensibilities of anyone." -- *Charles Darwin, The Origin Of Species, 1869.*

"With over 50 foreign cars already on sale here, the Japanese auto industry isn't likely to carve out a big slice of the U.S. market." -- *Business Week, Aug 2, 1968.*

"That Professor Goddard with his 'chair' in Clark College and the countenancing of the Smithsonian Institution does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react--to say that would be absurd. Of course, he only seems to lack the knowledge ladled out daily in high schools." -- *1921 New York Times editorial about Robert Goddard's revolutionary rocket work. The remark was retracted July 17, 1969.*

"You want to have "Drill for oil? You mean drill into the ground to find oil? You're crazy." -- *Workers whom Edwin L. Drake tried to enlist to drill for oil in 1859.*

"Stocks have reached what looks like a permanently high plateau." -- *Irving Fisher, Professor of Economics, Yale University, 1929.*

"There is not the slightest indication that nuclear energy will ever be obtainable. It would mean the atom would have to be shattered at will." -- *Einstein, 1932.*

"The bomb will never go off. I speak as an expert in explosives." -- *Admiral William Leahy, U.S. Atomic Bomb Project.*

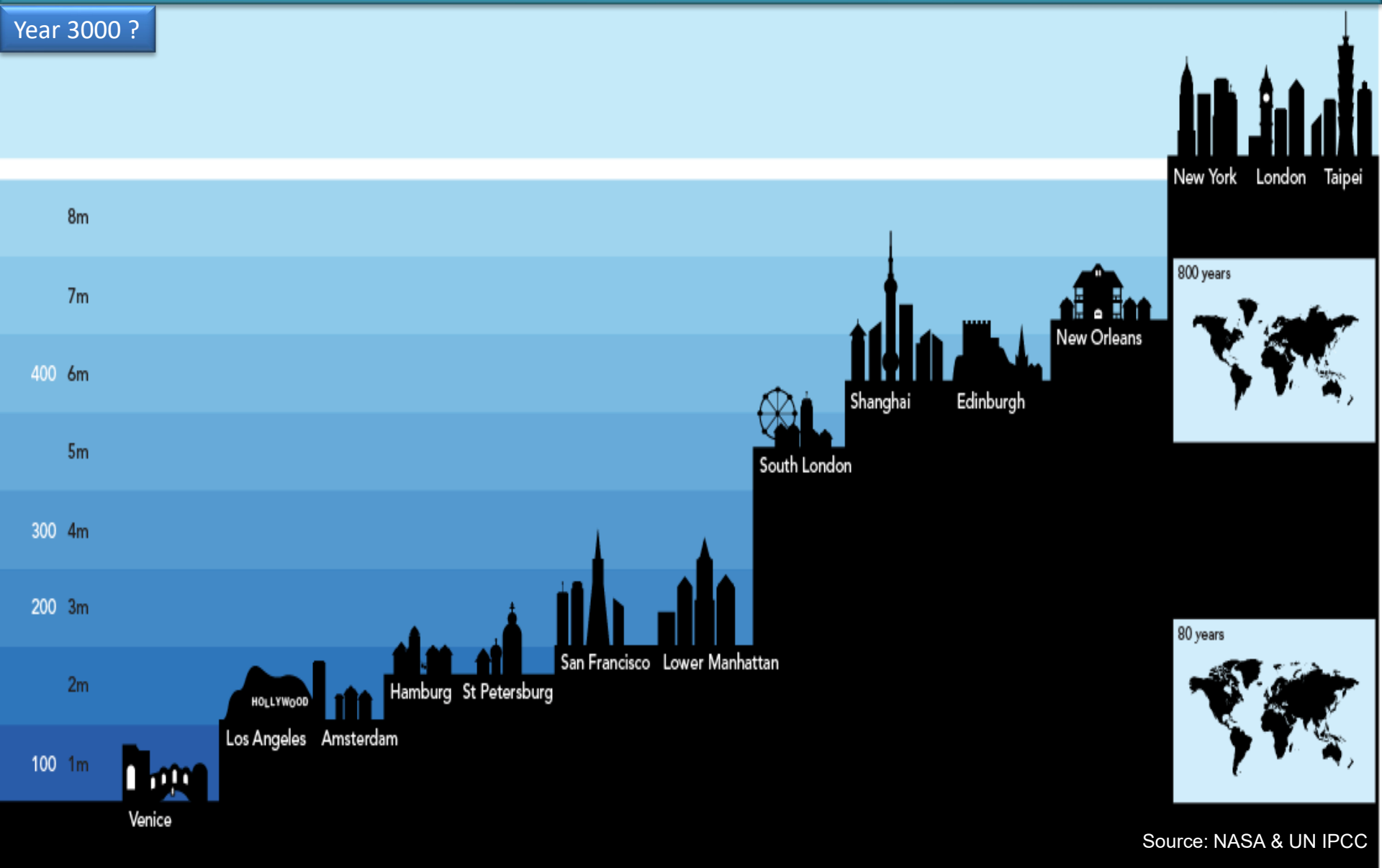
"Airplanes are interesting toys but of no military value." -- *Marechal Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre.*

"There will never be a bigger plane built." -- *A Boeing engineer, after the first flight of the 247, a twin engine plane that holds ten people.*

"Louis Pasteur's theory of germs is ridiculous fiction." -- *Pierre Pachet, Professor of Physiology at Toulouse, 1872.*

"The abdomen, the chest, and the brain will forever be shut from the intrusion of the wise and humane surgeon." -- *Sir John Eric Ericksen, British surgeon, 1873.*

Think Energy - Expansion of water 1 m / 100 years → Re-Visit Venice, soon?



Source: NASA & UN IPCC

ENERGY

MICRO-SCALE MANUFACTURING SUPPLY CHAINS

Photo Bio C4 Reactor

C4 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C4 REACTOR

INSIDE BIO-REACTOR

ROTARY SHAKER

AERATION FOR GROWTH

INPUT

MICRO-ORGANISMS
MINIMAL MEDIA

EXPOSE TO SUNLIGHT

OUTDOOR APPLIANCE

EPUC4

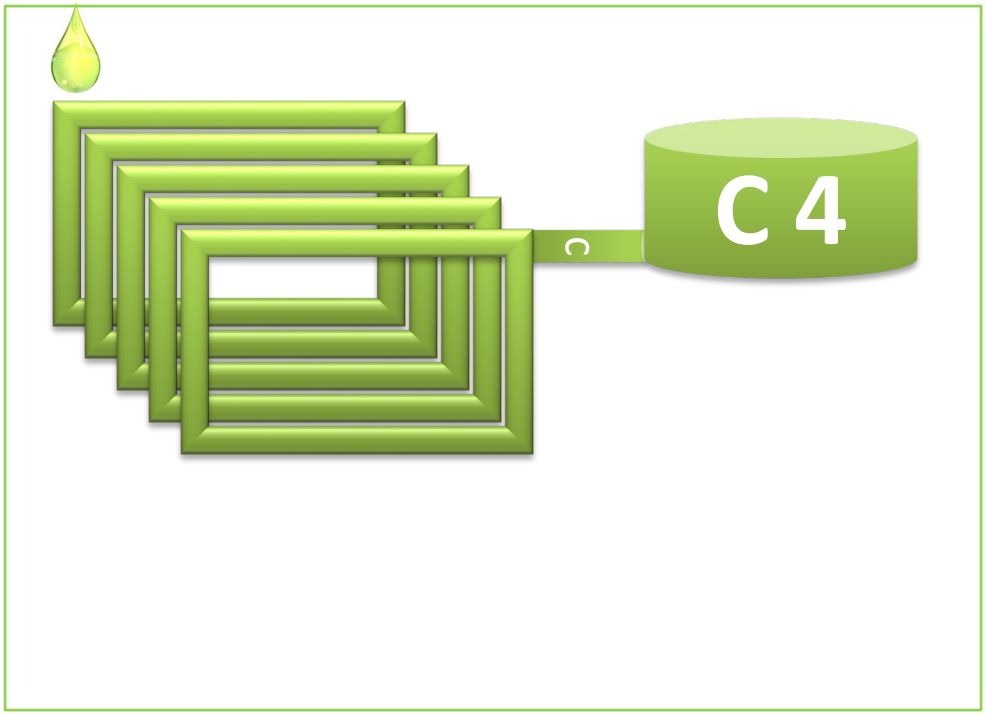
OUTPUT

DILUTE BUTANOL ?
PURIFIED BUTANOL ?
BUTANOL MIXTURE ?

EPUC4 - C4 EXTRACTION PURIFICATION UNIT

FUEL GRADE C4

BUTANOL



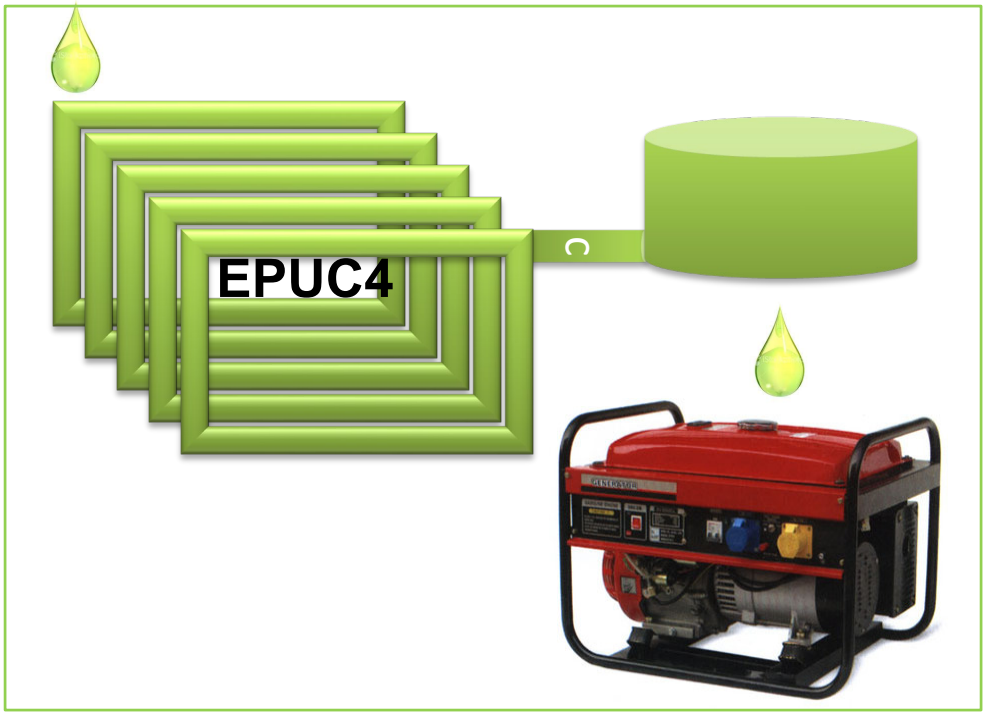
C4 - BUTANOL

low efficiency conversion to

ELECTRICITY

by commercially available

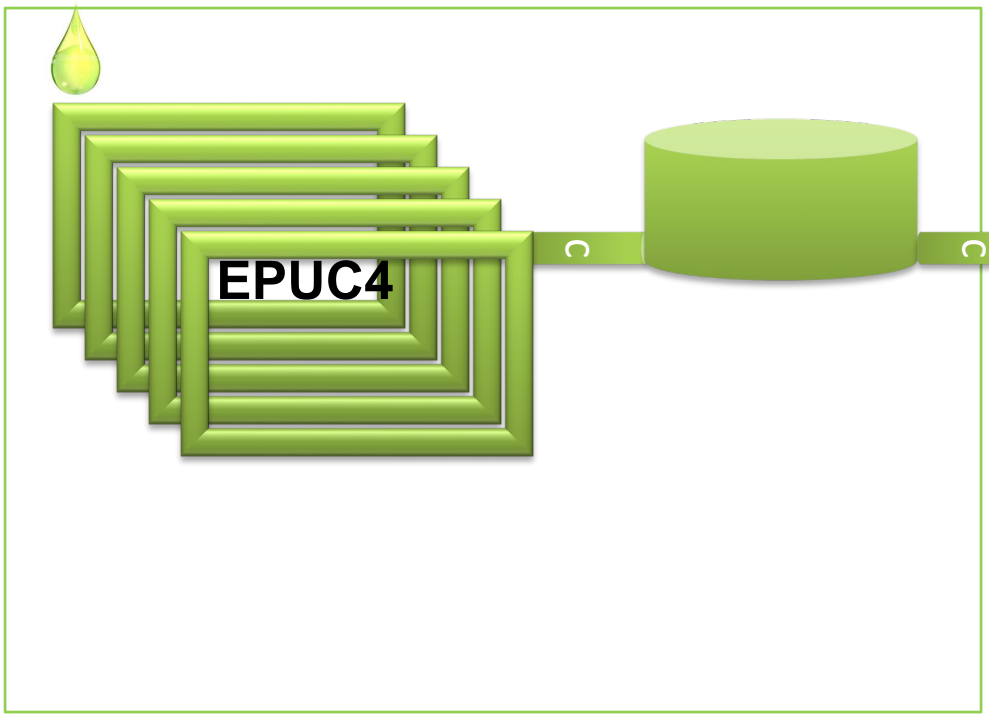
GENERATOR



BUTANOL

DIRECT USE IN CARS

TRANSPORTATION FUEL



BUTANOL ♦ ELECTRICITY

for

ELECTRIC VEHICLES
DOMESTIC USE
SELL TO GRID

EPUC4

C4 PRODUCT DEVELOPMENT

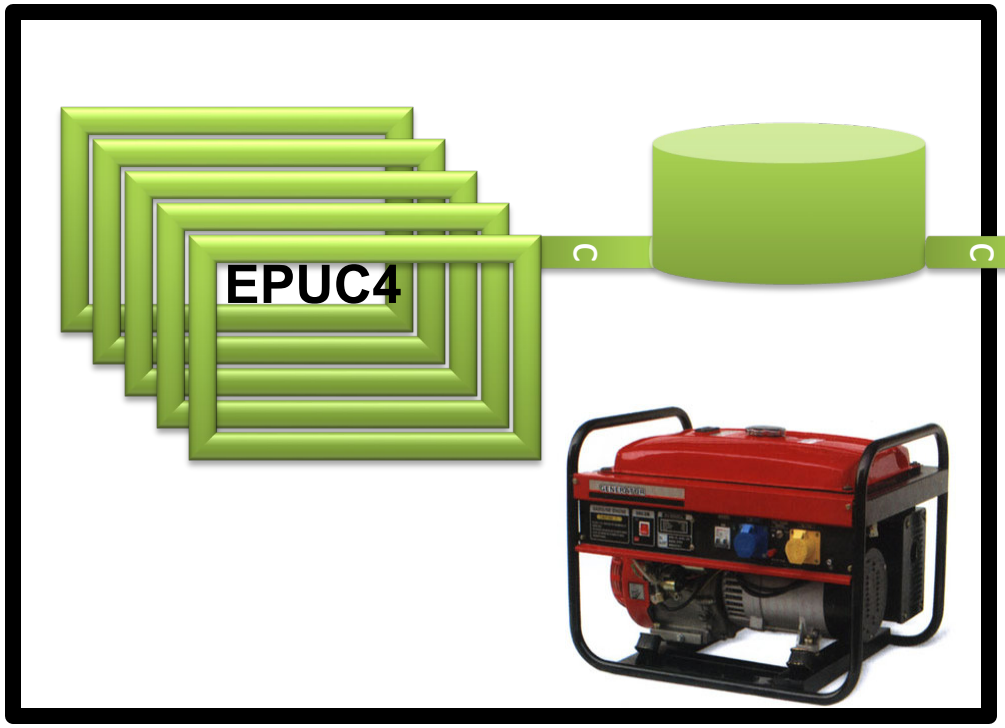
SOLAR DEPENDENT PHOTO BIO C4 REACTOR

OUTDOOR APPLIANCE

C4 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C4 REACTOR

INTEGRATED INDOOR C4 UNIT ILLUSTRATION



C4 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C4 REACTOR

COMPLETE PRODUCT UNITS ILLUSTRATED

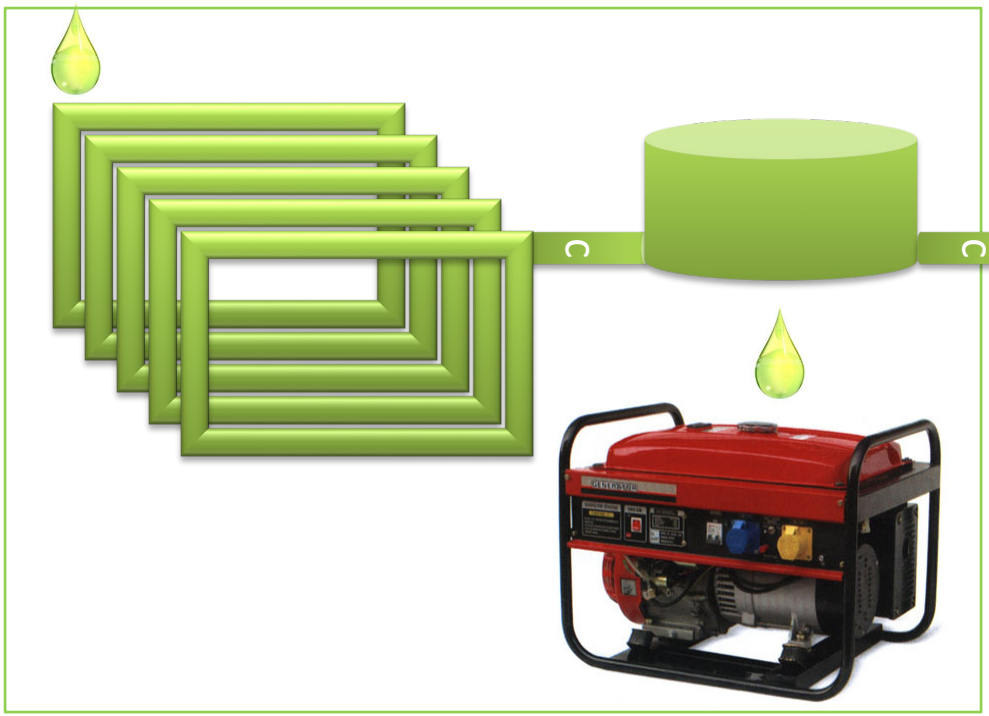


Photo-Bio Glucose [C6] Production

New Line of Global Manufacturing Business

New Commodity in Renewable Energy Supply Chain

C6 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C6 REACTOR

INSIDE C6 BIO-REACTOR

ROTARY SHAKER

AERATION FOR GROWTH

INPUT

MICRO-ORGANISMS
MINIMAL MEDIA

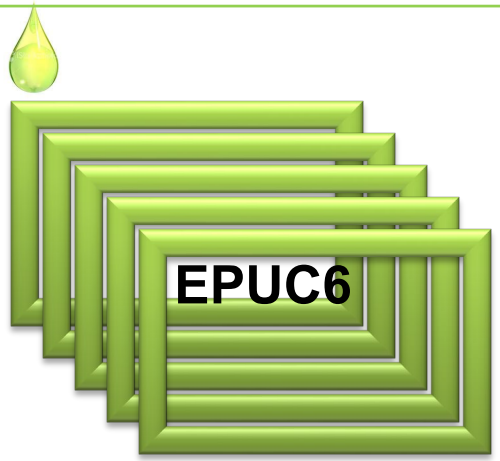
EXPOSE TO SUNLIGHT

OUTDOOR APPLIANCE

C6 REACTOR OUTPUT

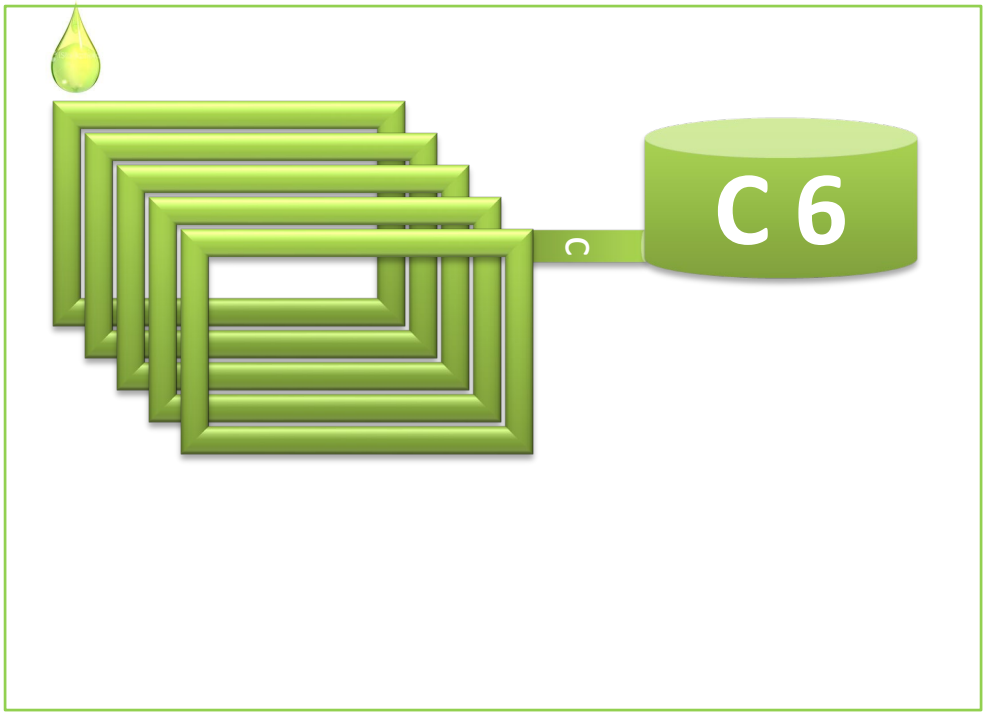
DILUTE GLUCOSE ?
GLUCOSE PASTE ?
GLUCOSE MIXTURE ?

EPUC6 - C6 EXTRACTION PURIFICATION UNIT



GLUCOSE

MARKET COMMODITY



C6 PRODUCT DEVELOPMENT

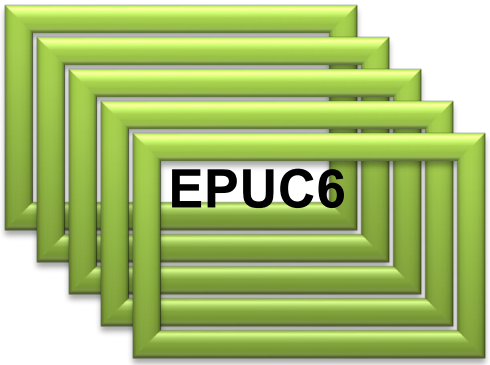
SOLAR DEPENDENT PHOTO BIO C6 REACTOR

OUTDOOR APPLIANCE

C6 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C6 REACTOR

INDOOR EPUC6



C6 PRODUCT DEVELOPMENT

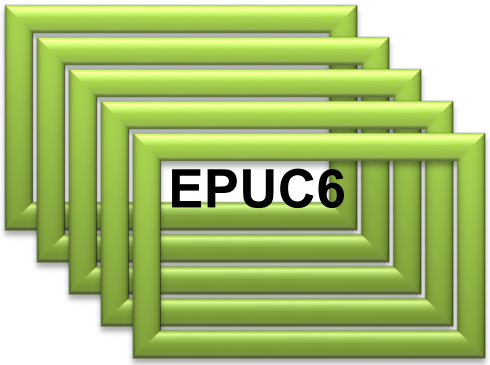
SOLAR DEPENDENT PHOTO BIO C6 REACTOR

C6 STORAGE

C6 PRODUCT DEVELOPMENT

SOLAR DEPENDENT PHOTO BIO C6 REACTOR

COMPLETE PRODUCT SET (ILLUSTRATION)



INSOLATION AGNOSTIC

C4 PRODUCT DEVELOPMENT

SOLAR INDEPENDENT
BIO C4 REACTOR

Insolation Independent

Photo-C6 Dependent C4 Bio-Reactor

Schematic Product Design

INPUT

MICRO-ORGANISMS

+

PHOTO C6 MEDIUM

INDOOR APPLIANCE

OUTPUT

DILUTE BUTANOL ?
PURIFIED BUTANOL ?
BUTANOL MIXTURE ?

EPUC4 - C4 EXTRACTION PURIFICATION UNIT

FUEL GRADE C4

BUTANOL

C4 - BUTANOL

low efficiency conversion to

ELECTRICITY

by commercially available

GENERATOR

BUTANOL

DIRECT USE IN CARS

TRANSPORTATION FUEL

BUTANOL ♦ ELECTRICITY

for

ELECTRIC VEHICLES
DOMESTIC USE
SELL TO GRID

EPUC4

iC4 PRODUCT DEVELOPMENT

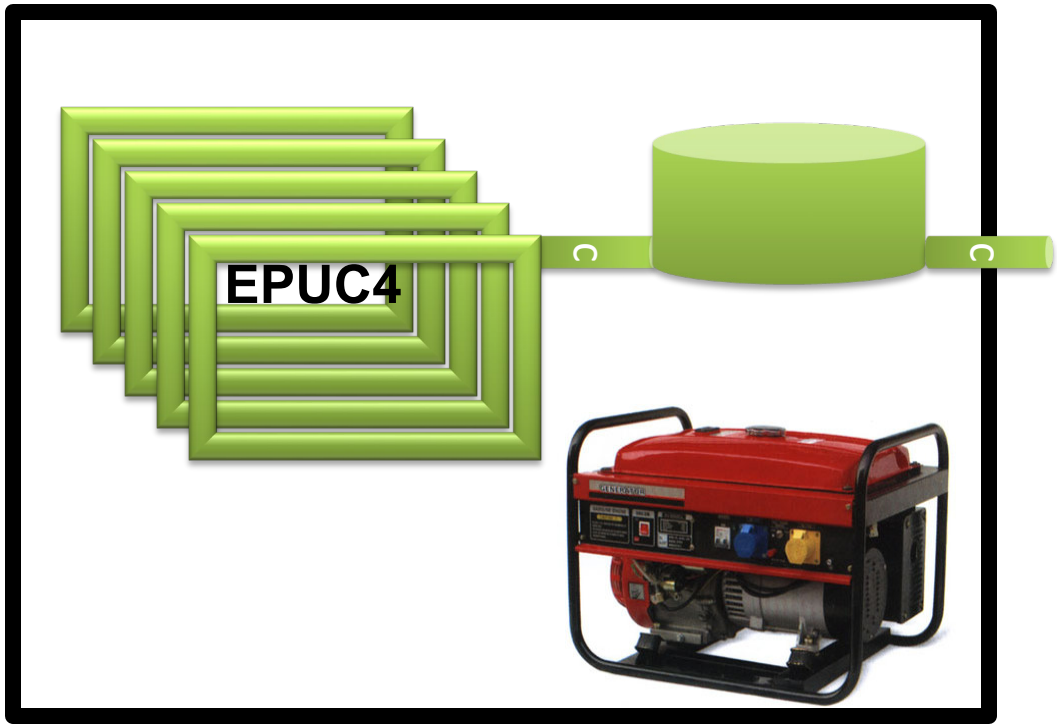
SOLAR INDEPENDENT PHOTO BIO C4 REACTOR

INDOOR APPLIANCE

C4 PRODUCT DEVELOPMENT

SOLAR AGNOSTIC PHOTO BIO C4 REACTOR

INTEGRATED INDOOR C4 UNIT ILLUSTRATION

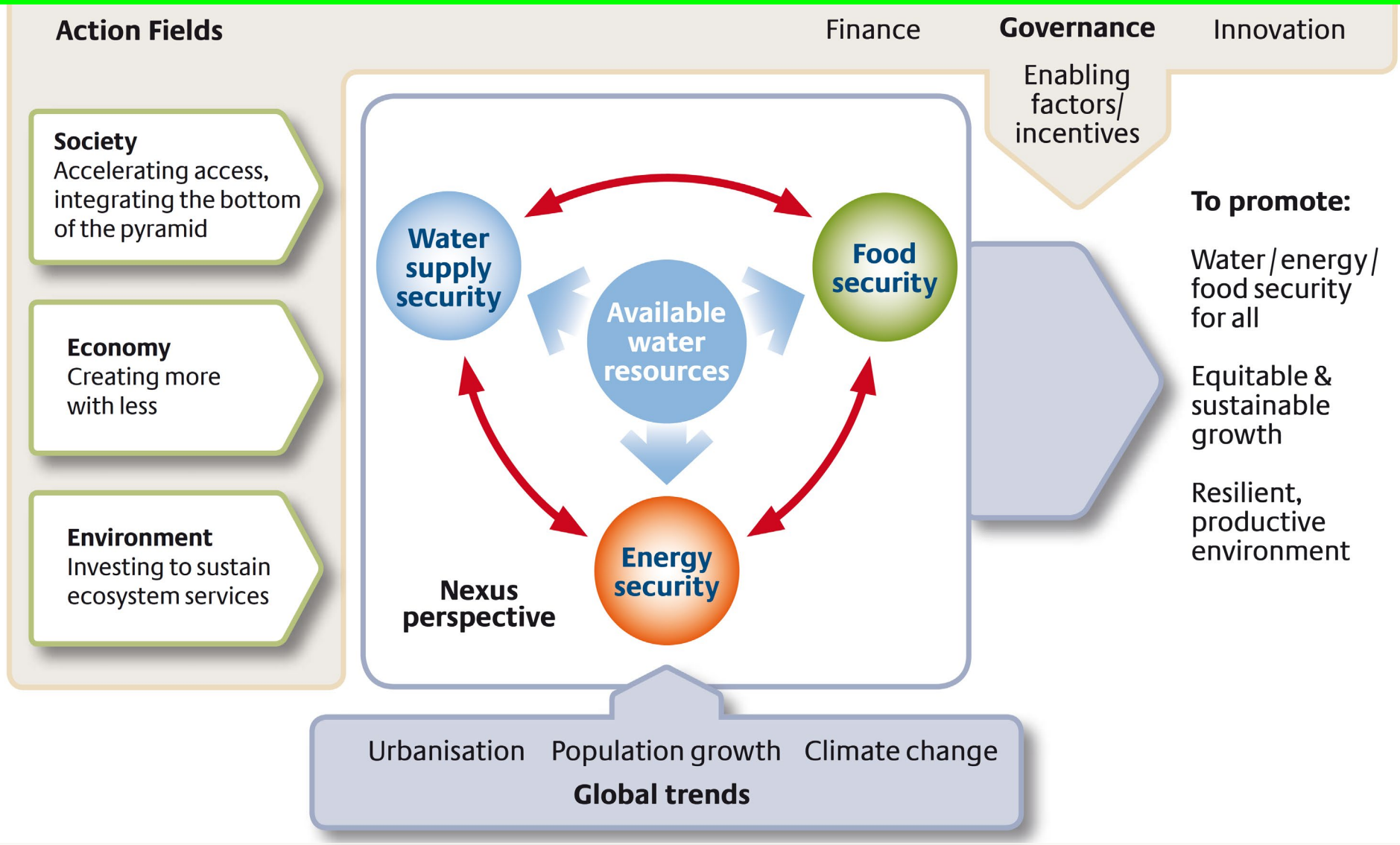


SOLAR AGNOSTIC C4
PRODUCT DEVELOPMENT

SOLAR INDEPENDENT
PHOTO BIO C4 REACTOR

**COMPLETE PRODUCT
UNITS ILLUSTRATED**

Food-Energy-Water Nexus



Hoff, H.(2011) Understanding the Nexus. Bonn 2011 Conference: Water, Energy and Food Security Nexus. Stockholm Environment Institute, Sweden.
holger.hoff@sei-international.org ◆ http://wef-conference.gwsp.org/fileadmin/documents_news/understanding_the_nexus.pdf

Water for Food

Ranges of water productivity of different crops in kcal per m^3 and USD per m^3 of water[146]

	Wheat	Potato	Tomato	Apple
kcal per m^3	660–4000	3000–7000	1000–4000	520–2600
USD per m^3	0.04–1.2	0.3–0.7	0.75–3.0	0.8–4.0

Table 3. Global average water productivity (in kcal per m^3), and consumptive water-use from grazing (in per cent), of selected livestock products[148]

	Meat from beef cattle	Meat from sheep and goats	Milk from dairy cattle	Meat from pigs	Meat from poultry	Eggs from poultry
Global average water productivity in kcal / m^3	34	30	332	666	371	578
Water-use from grazing in %	84	75	80	0	0	0

Water for Sanitation

Rapid monitoring and evaluation of a community-led total sanitation program using smartphones

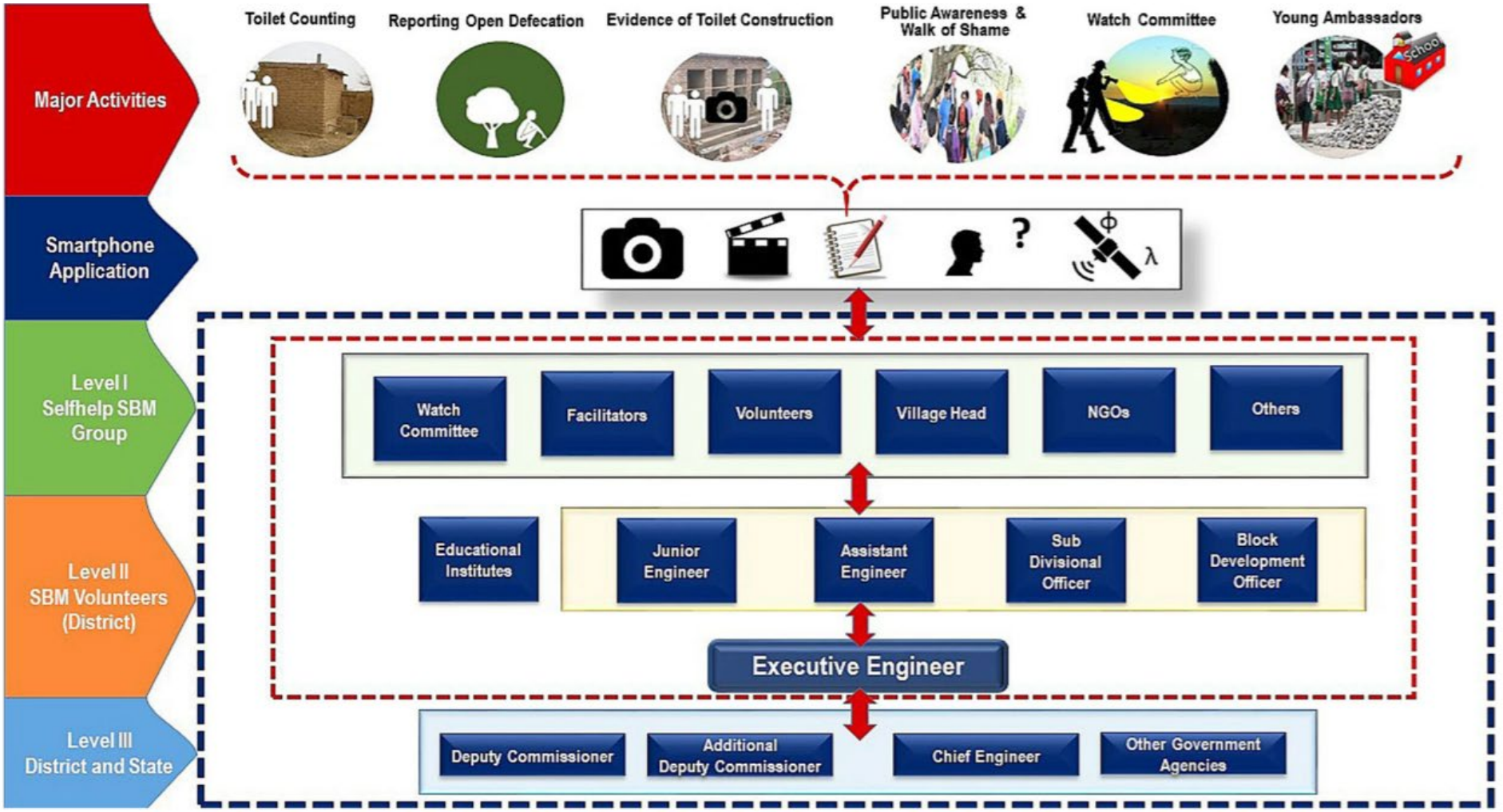
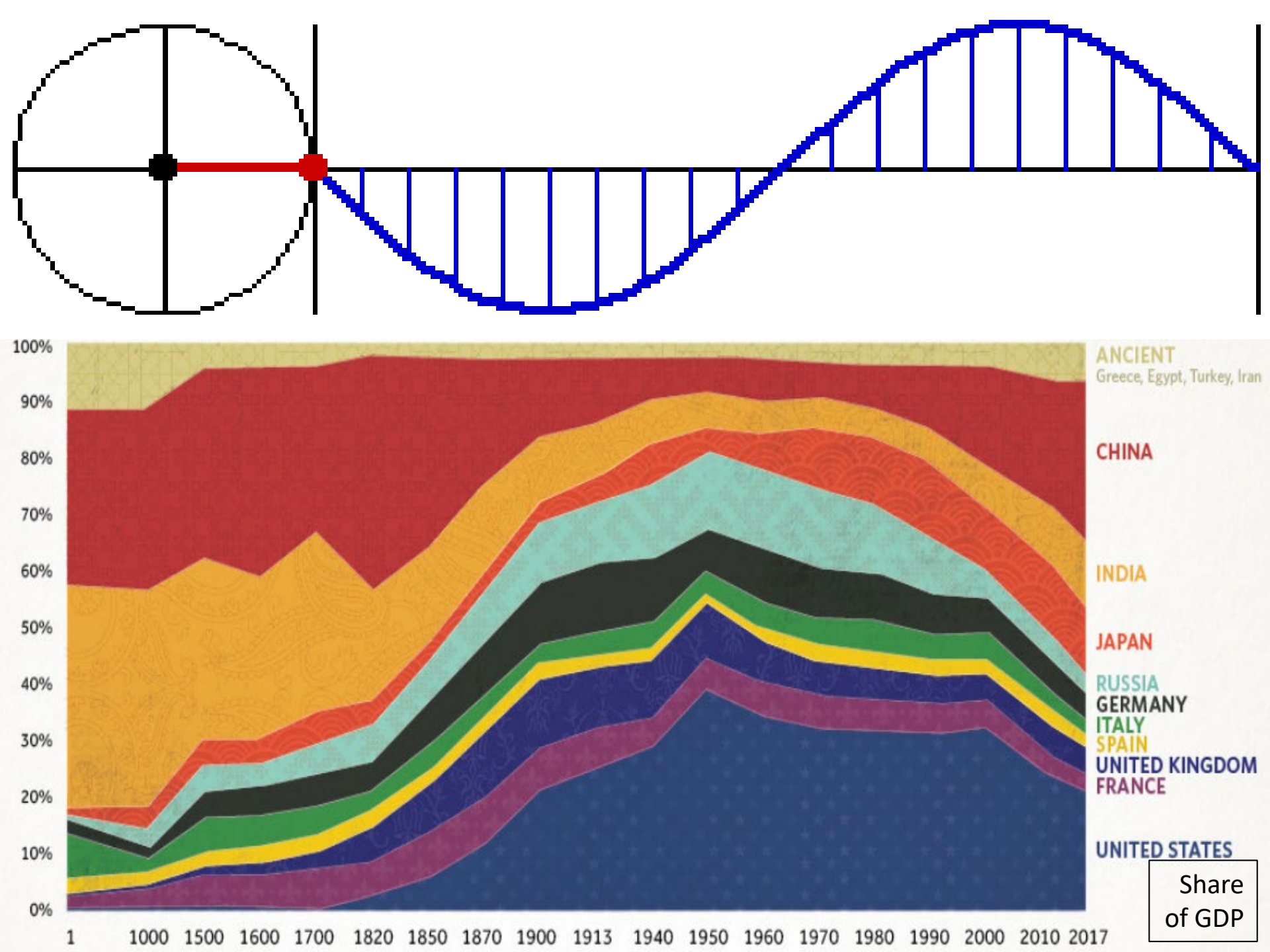


Fig. 2 Process of smartphone-based IMA in CLTS

https://link.springer.com/content/pdf/10.1007%2Fs11356-018-3300-8.pdf


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
1000
1500
1600
1700
1820
1850
1870
1900
1913
1940
1950
1960
1970
1980
1990
2000
2010
2017
ANCIENT
Greece, Egypt, Turkey, Iran
CHINA
INDIA
JAPAN
RUSSIA
GERMANY
ITALY
SPAIN
UNITED KINGDOM
FRANCE
UNITED STATES
Share of GDP

Continuious Imagination, Invention, Innovation

165 years	169 years	151 years	179 years	166 years

Magnetic Compass 1275

Gutenberg Press 1440

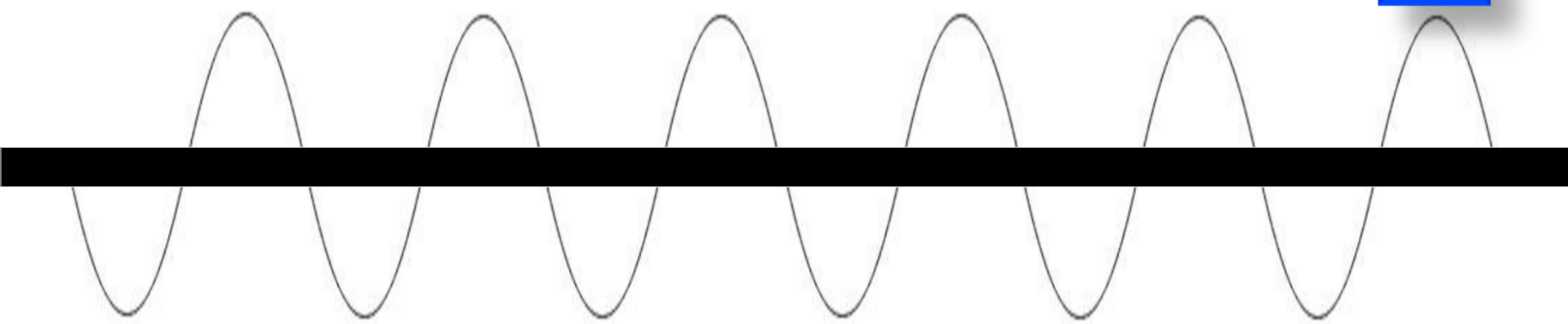
Galileo Telescope 1609

James Watt Steam Engine 1760

Atanasoff Computer 1939

2090-2120

2105



1190 Two Truths Theory

1361 Italian Renaissance

1530 Copernican Astronomy

1687 Newtonian Mechanics

1859 Darwinian Evolution

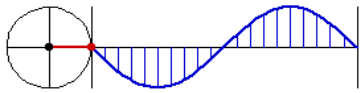
2026

2015-2030

171 years	169 years	157 years	172 years	167 years

Social, Cultural, Economic, Paradigm Shifts

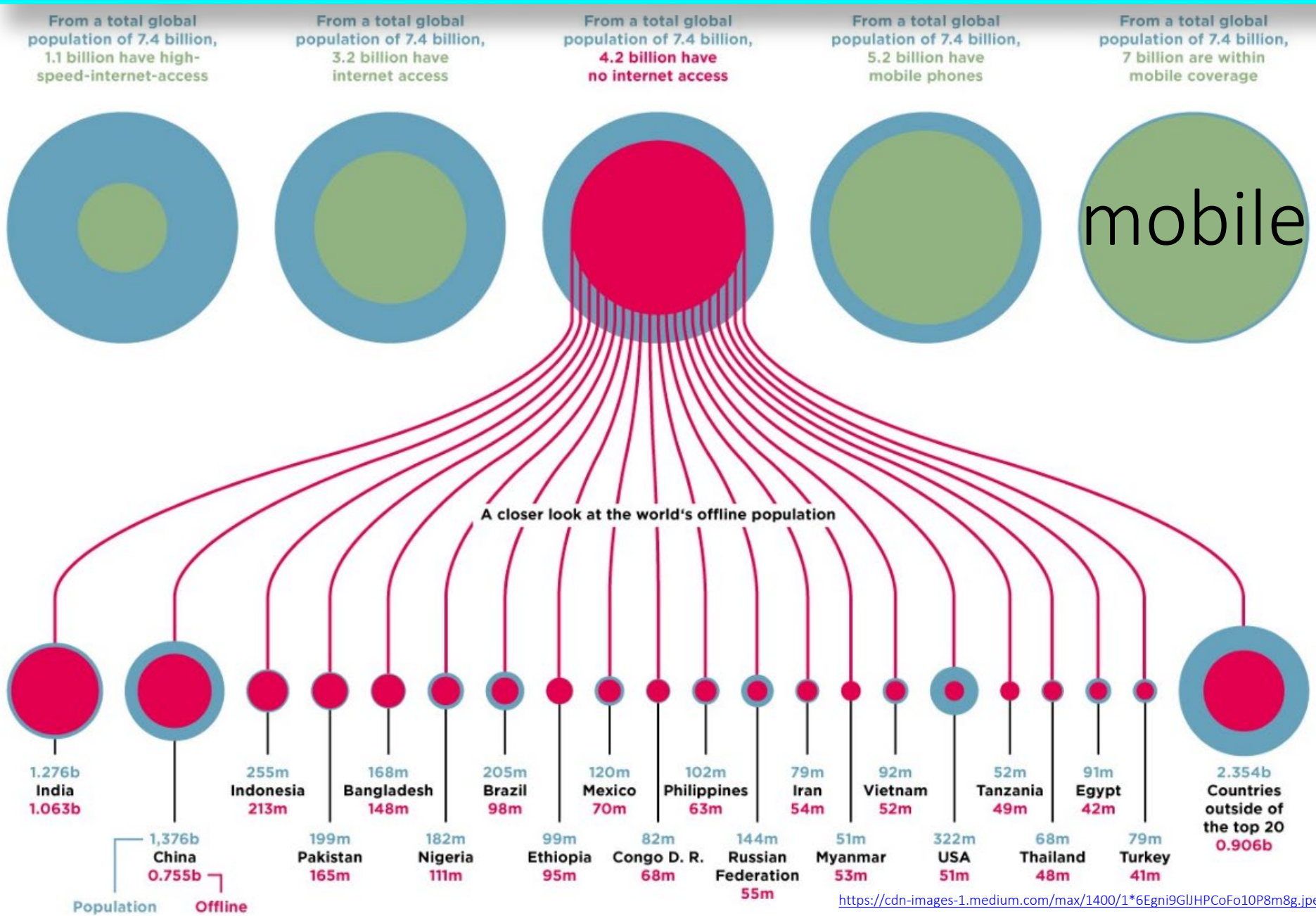
Adapted from Norman Poire and loosely based on Kondratieff Waves



Unsustainable and Misaligned Economics of Technology triggers a Porous Pareto Partition Between the Haves and the Have Nots: Can Democratization of Distributed Data Catalyze the Dissemination of Digital Dividends?

Economics of technology must rapidly reduce transaction costs from being a barrier to entry into markets of billions. The future is not about product sales. The service economy will be driven pay-a-penny-per-use service paradigm.

The Digital Chasm: 4.2 billion (57%) have no access to internet



https://cdn-images-1.medium.com/max/1400/1*6Egni9GlJHPCoFo10P8m8g.jpeg

https://dspace.mit.edu/handle/1721.1/123984 ◆ https://dspace.mit.edu/handle/1721.1/111021

ARE YOU REDI ?

Research Education Development Innovation

Science must serve society

Food, Energy, Water, Sanitation, Health, Education

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