LENR *Cars*

Self Powered LENR Electric Vehicles

LENR Powered Electric Vehicles

ILENRS-12

Nicolas Chauvin

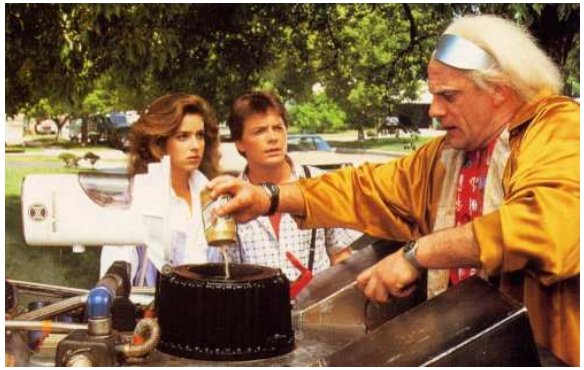
LENR Cars – CEO

July 2012

Why LENR Cars ?

- Simple Value Proposition:
  - Zero emission vehicles that cost less, that require less maintenance, that can be driven anytime without the need of an infrastructure
- Marketing & Engineering
  - Marketing ⇨ What customers want ⇨ not a new concept (BTTF 1 & 2)
  - Engineering ⇨ How to make it
  - More important: Engineering ⇨ When it can be done !

Timing Is Everything



Why Now is a Good Timing ?

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- A. Rossi, Leonardo Corp.
  - Stable reactors producing heat > 600°C
  - 20 new-gen 10 kW reactors currently running in Florida
  - New-gen reactors running continuously for 6+ weeks
  - Currently collecting 20’000 hours of test data
  - Will present data in a couple of weeks/months
- Defkalion GT
  - Reactor running at over 650°C
  - COP over 30
  - Will present final Hyperion prototype soon (August ?)
- Brillouin Energy Corp.
  - Starts working on 3rd generation electrolytic system
- JET Energy
  - NANOR cell running for several months

State of The Union 2012

- Barack Obama, Jan 24th 2012

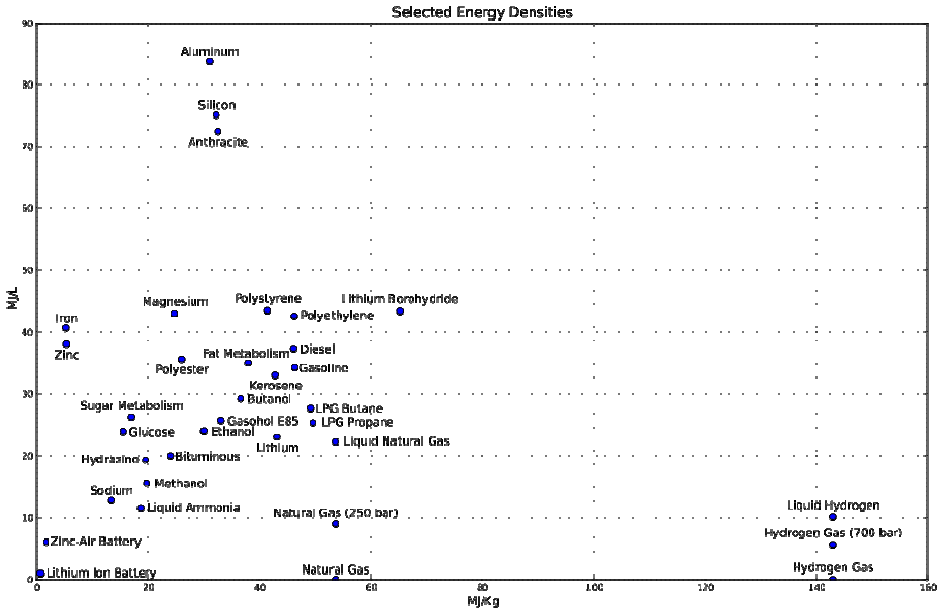
  « So far, you haven't acted. Well, tonight, I will. I'm directing my administration to allow the development of clean energy on enough public land to power 3 million homes. And I'm proud to announce that the Department of Defense, working with us, the world's largest consumer of energy, will make one of the largest commitments to clean energy in history -– with the Navy purchasing enough capacity to power a quarter of a million homes a year.»

- US Navy is working on:
  - Underwater solar plants
  - Wave & tidal harvesting
  - ? LENR plants with Rossi ?

Why LENR Cars ?

LENR Cars
Self Powered LENR Electric Vehicles

- Major pain point of electric vehicles: Batteries
  - Cost: $250 - $350 / kWh (Li-ion) ⇨ over US$ 5’000 additional cost
  - Weight & Low Energy Density: 150 Wh/kg (Li-ion) 350 Wh/kg (Li-S)
  - Geopolitical concerns with lithium resources (Chile, Bolivia)
  - Reliability ⇨ requires control electronics
  - Range limitations ⇨ dependency on infrastructure
  - Safety



EV Infrastructure – New Behaviors

LENR Cars
Self Powered LENR Electric Vehicles

How LENR Power Could Fit in a Car ?

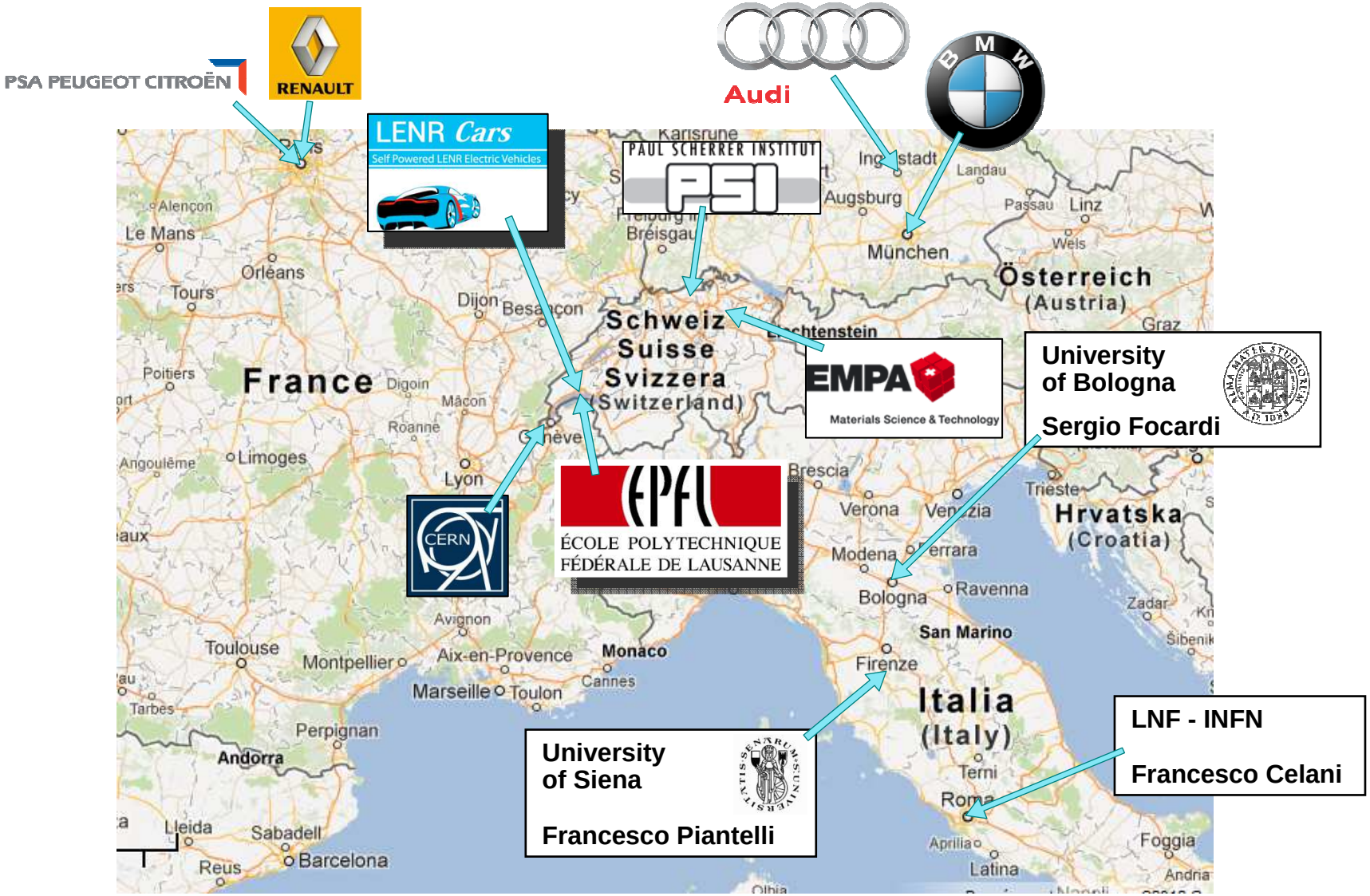
- 10 kW to 50 kW thermal generator are emerging
- Compatible power density: 1-2 kW_T/kg ⇨ 0.1-0.5 kW_e/kg
- Unparalleled energy density: ~ 4 MWh_T/kg ⇨ ~ 1 MWh_e/kg
  (except with radioactive nuclear fission solutions)
- Compatible dimensions / volume: ~ 1 kW_T/l ⇨ 0.25 kW_e/l
- Affordable price range: $5'000 - $10'000 (incl. thermoelec. conv.)
- Highly safe under crash situation (compared to batteries)
- Negligible cost of fuel
- Cherry on the pie: **Clean Energy**

LENR Cars Company

LENR Cars: Company Strategy

1. **Develop IP** relative to the transportation industry
   - File patent applications
2. **Build network of partners** with technical expertise:
   - Low Energy Nuclear Reactions (LENR) : Defkalion GT
   - Nano materials: EMPA
   - Thermoelectric conversion: PSI
   - Electric vehicles: Tesla Motors, PSA, Green GT,
3. **Demonstrate technical feasibility**
   - Demonstrate small scale LENR reaction with reproducible experiments
   - Build electric car prototypes
4. **License technology**
   - To major automotive suppliers
   - To electric vehicle manufacturers
   - To manufacturers of other type of transportation (aircraft, trains, boats, ...)

LENR Cars: Geographical Situation



LENR Cars: Closer Look

LENR Cars
Self Powered LENR Electric Vehicles

PSA PEUGEOT CITROËN
R&D Center

LENR Cars
Self Powered LENR Electric Vehicles

green GT

NISSAN

INFINITI

CERN

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

LENR Cars Team

- Nicolas Chauvin - CEO
  - Eng. in Micro-Engineering (EPFL)
  - Business School (Lausanne)
  - New technology expert and innovation leader at Logitech
  - Strong expertise in many engineering fields (ME, EE, OPT, FW, SW)
  - Inventor of a dozen of patents in medical, consumer electronics & transportation fields
  - Researcher for NASA-Ames and CMU
  - Founder of 2C3D (Comp. Ass. Surgery) and AmmA Interactive (SW)
  - IT Project Manager at Nestlé

- Antoine Guillemin - Director of R&D
  - PhD in Physics (EPFL), M.Sc in Nuclear Physics
  - Leading expertise in energy-efficient systems and renewable energy
  - Founder Neurobat (high-eff. heating control systems) and Adhoco (home automation)
  - SW and HW developments and bringing sophisticated technologies to market
  - Highly experienced in leading complex R&D development programs, managing technical teams and budgets

LENR Powered Car

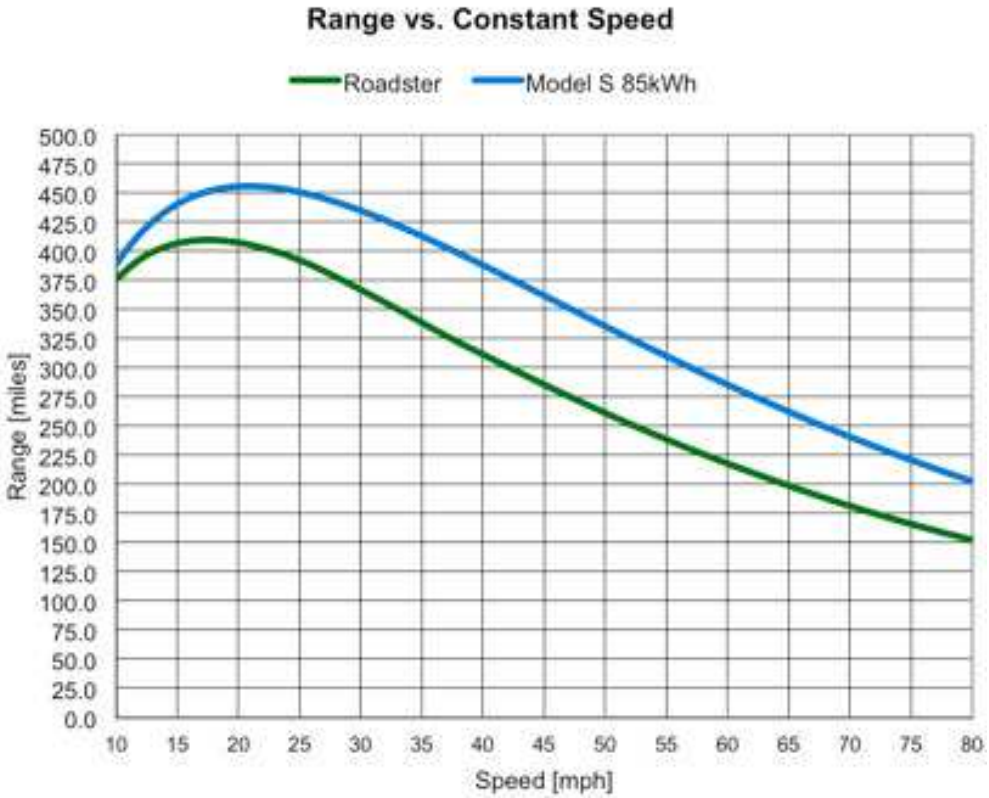
How Is It Possible?

Typical Electric Vehicle Specifications

	Renault Zoé	Nissan Leaf	Tesla Model S Perf.
Battery Capacity	22 kWh (Li-ion)	24 kWh (Li-ion)	85kWh (Li-ion)
Typical Range	200 km	175 km	480 km
Motor Peak Power	65 kW	80 kW	325 kW
Avg. Power Cons.	11.0 kWh / 100 km	13.7 kWh / 100 km	17.7 kWh / 100 km
Fast Charge	80% in 30min (42kW - 63A)	80% in 30min (44kW / 400V / 110A)	55% in 30min
Bat. Spec. Power		525 W/kg	
Bat. Spec. Energy		140 Wh/kg	
Battery Weight		171 kg / 218 kg	
Estim Bat. Cost		US$ 18’000.-	US$ 42’000.-

EV Efficiency & Range

- EV power consumption is highly depending on:
  - Vehicle speed
  - Vehicle weight

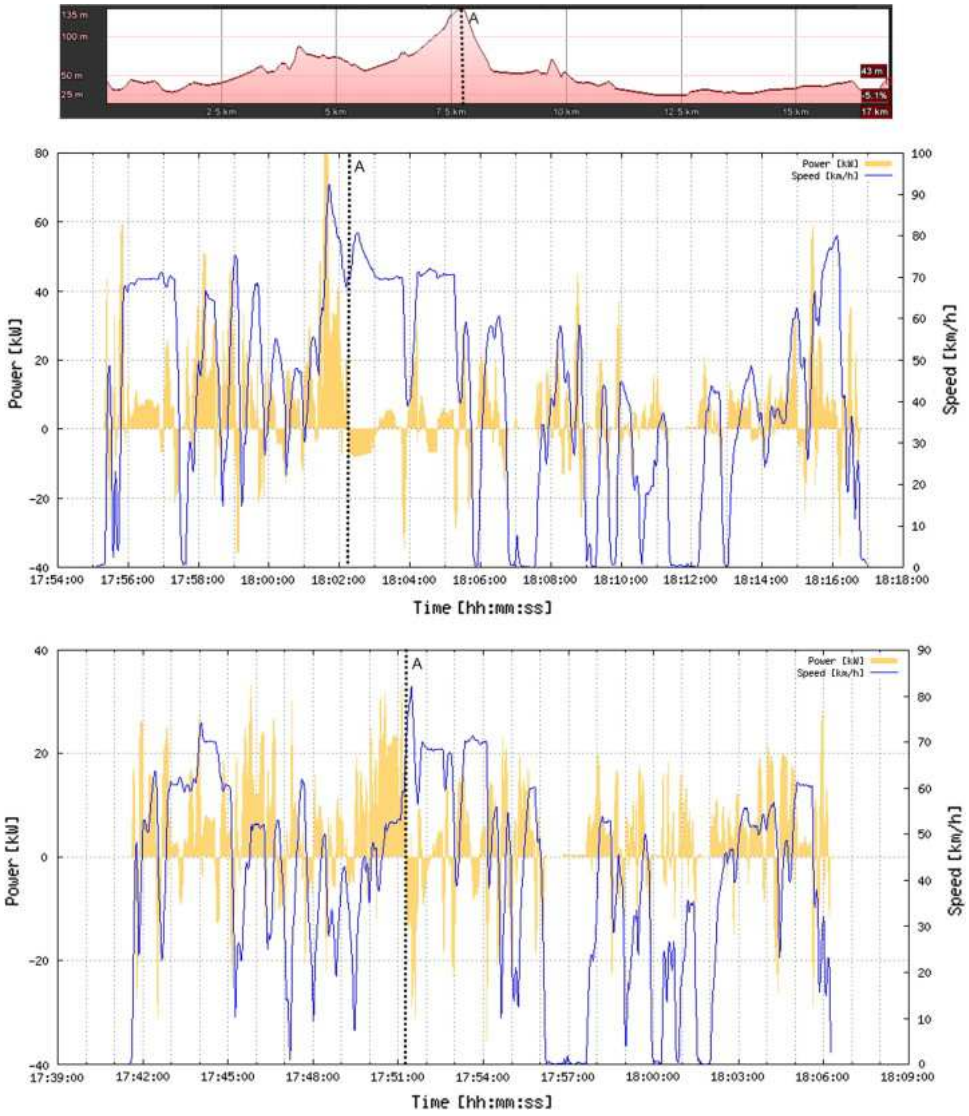


Source: Tesla Model S Efficiency & Range

Power Consumption Elasticity

- High variation of power requirement over time
- Peak power: 60 to > 100 kW
- Average power: 10 to 20 kW
- Avg. power is 5 to 10 times smaller than peak power

- Need of an energy buffer to absorb power peaks, either:
  - batteries / supercaps
  - fly wheel
  - combination



Electrical Power From Thermal Source

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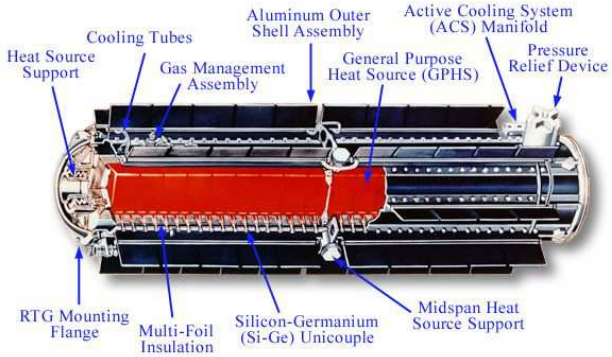
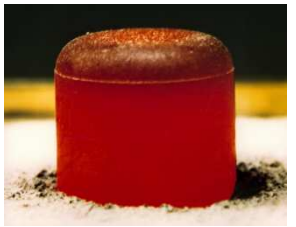
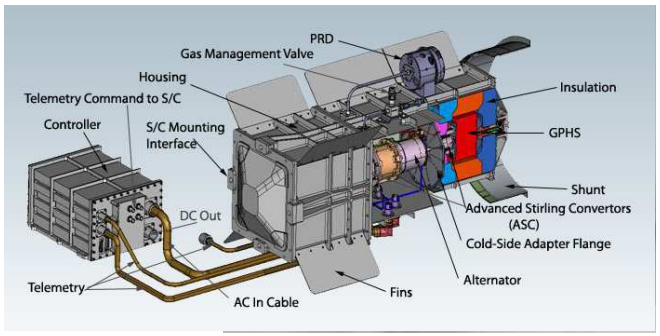
- RTG (Radioisotope Thermoelectric Generator)
  - Pellet of $^{238}PuO_2$
  - Thermopile (array of thermocouples, Bi_2Te_3)
  - Typical power: 470We (Voyager 1 & 2)
  - Typical conversion efficiency: 4% – 7%
  - Long life time: > 20 years

Cassini probe GPHS-RTG





- ASRG (Advanced Stirling Radioisotope Generator)
  - ASC (Advanced Stirling Converter, SunPower Inc.)
  - Free piston Stirling engine design
  - Typical power: 140We
  - Typical conversion efficiency: > 25%



iCar Gen 1 Prototype

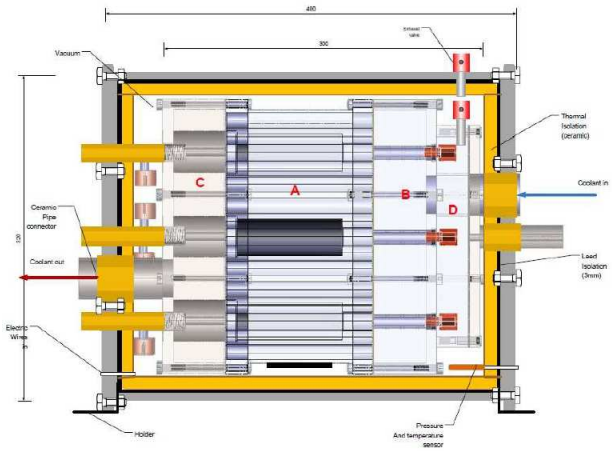
1st Generation of the Ideal Car

iCar Gen 1 EV

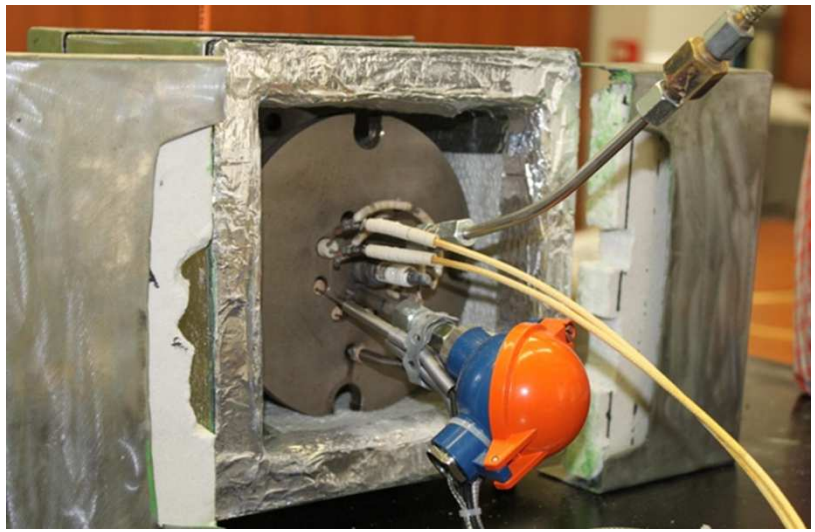
- Tesla Model S Performance
  - Best battery capacity: 85 kWh
  - Best overall EV car available
    - comfort, performance, range
  - Hood & trunk storage space

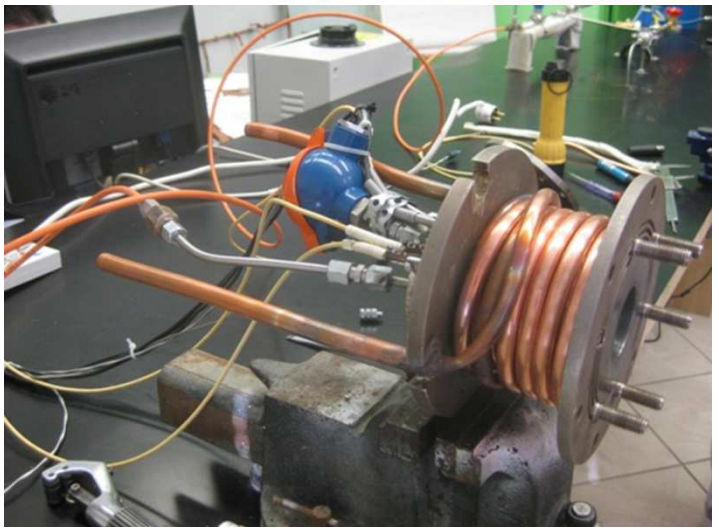
LENR Generator

- Defkalion Hyperion 45kW Serie B Prototype
  - Dimensions: 55cm x 45cm x 42cm
  - Weight: 51 kg
  - Electrical energy consumption: < 310 Wh/h
  - Max output temperature: 414°C
  - COP: > 32



Hyperion Kernel and Inbox design (multi-reactor model). Labels used in Spec sheet





Energy Harvesting Introduction

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- Solar Keyboard

- Avg. Power Consumption: 55uW
- Peak Power Consumption: 1.3mW
- Charges 8h per day
- Small battery storage
- Optimizations:
  - Power consumption (-50%)
  - DC-DC power management
- Power Generation:
  ~ 250 uWh/h for 8h/day
  ⇨ 2 mWh per day

- iCar: LENR EV 1st Gen

- Avg. Consumption (@ 100 km/h):
  - 180 Wh/km (280 Wh/mile)
  - 10.8 kWh per day (60 km / 38 miles)
- Large battery storage: 85 kWh
- Self powered range:
  - 420km / week (260 miles/week)
  - ~ 22'000km / year (13'600miles / y)
- Can charges up to 24h per day
  - 450 Wh/h ⇨ 10.8 kWh per day

How To Meet Objectives: iCar Gen 1

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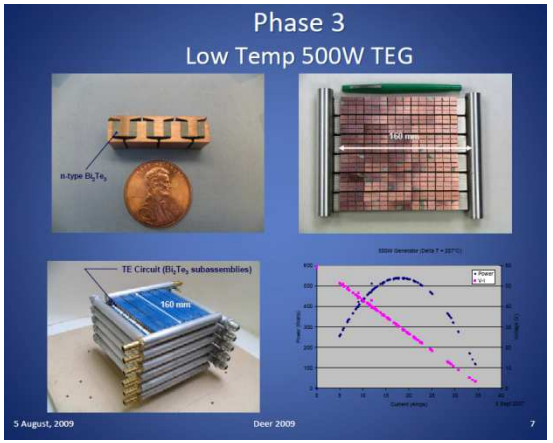
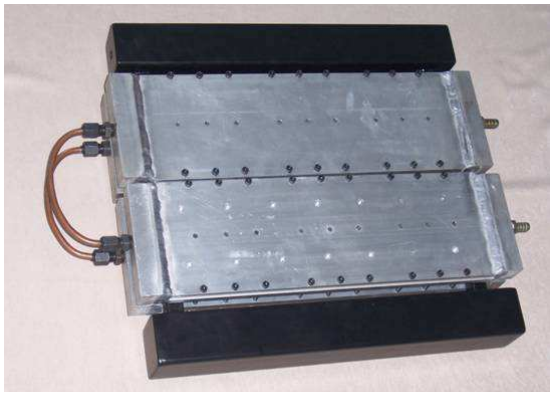
Self Powered LENR Electric Vehicles

- Target: electrical power available for continuous charging: 450 W_e
- Battery charging management efficiency: ~90%
- Target: continuous electrical production: 500 W_e
- LENR generators: ~ 45 kW_T
- Standard TEG with thermopiles (Bi_2Te_3)
  Seebeck effect, ~4.5 - 5.0% efficiency
- 5 TEG 500W modules
  at ΔT of 250°C => 2.25 kW_e
- With ~ 500W_e consumed by electric pumps & fans
  for the heating and cooling hydraulic system
- 1.25 kW_e are left as input for the LENR generators
- COP of 40 is required with such 1st Gen design
- Target: overall conversion efficiency: ~ 1.00%
- Patent pending





Thermoelectric Generator: TEG 500W

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Part Number	TEG500
Matched Load Output Power	500 W
Open Circuit Voltage	420VDC
Matched Load Output Voltage	200 VDC
Internal Resistance	58Ohm
Matched Load Current	3.5 A
Number of TEG Modules	48Pcs TEP1-12656-0.6
Hot Oil Flow Rate	＞0.25m3 /h
Hot Oil Input Temperature	＞250°C
Water Input Rate	＞0.5m3 /h
Input Water Temperature	＜30°C
Oil Pipe connector	Fillet DN15
Water inlet and outlet	Inlet and outlet 1/2
Dimension(long x Height x width)	560mm×500mm×120 mm
Weight	25（Kgs）

How to Evacuate Extra Heat ?

- Water cooling heat sink
  - Racing radiators combined with PC watercooler and PC fans
  - Front and rear radiator

- Racing aluminum radiator
  - Low cost
  - Good performance
  - PC fans ⇨ smaller form factor ⇨ better surface coverage
- PC watercooler
  - Very high performance
  - Low power pumps & fans
  - Heat dissipation: 2.8 kW (ΔT: +30°C, power consumption: 20 We)
  - Compact design ⇨ flexibility for positionning
  - Heavy : 12.5 kg for 2.8 kW
  - Expensive

Other Advantages of an Onboard Heat Source

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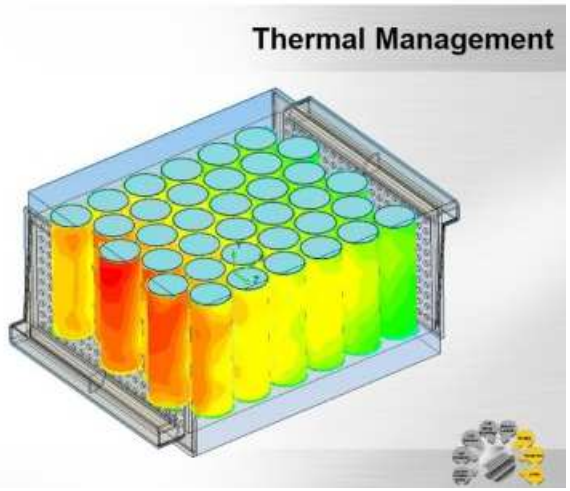
- No need of an electric heater
- Cooling source can be generated with an absorption refrigerator
  - but even more heat to evacuate
- Heat source and cooling source can be used in A/C
  - A/C does not consume electrical power (except fans)
- Battery thermal regulation can be operated the same way



iCar Gen 2

2nd Generation of the Ideal Car

iCar Gen 2

- Smaller battery energy buffer: ~ 30 kWh
- Better thermoelectric conversion efficiency
- Currently assessing:
  - Stirling engine converter: ~ 20 kW_e, 25% - 30% efficiency
  - Rankine engine converter: ~10-60 kW_e, 12% - 30% efficiency
  - Supercritical CO_2 closed Brayton cycle turbine: 10 to 60 kW_e
    > 40% efficiency at 250°C – 300°C, 140 bar

- Expected overall conversion efficiency: ~ 15 - 20%
- On-demand LENR generator(s): ~ 40 kW_T
- Available electrical output for recharge: ~ 8 kW_e
- Patent pending

Stirling Engine

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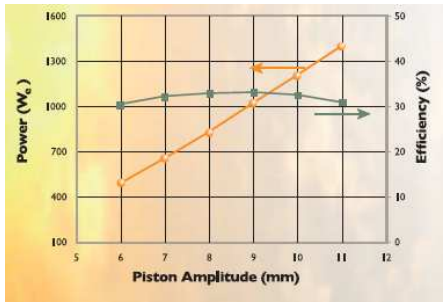
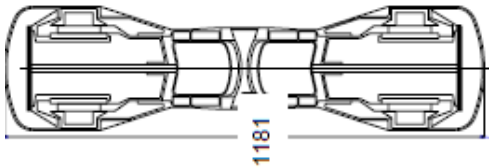


EG-1000 engine with non-recuperative propane burner

- Sunpower (Ohio)
  - EG-1000
    - Power output: 1.05 kWe
    - Efficiency: ~ 32%
    - Temp. ratio (Th/Tc): 2.7
    - Weight: 35 kg
  - CSSE Study:
    - Configuation: beta Stirling with dual opposed free pistons
    - Power output: 25 kWe
    - Temperature: heat source: 1050°K / cold source: 500°K
    - Specific power: ~ 200W/kg (incl. alternator)
    - Efficiency: ~ 30%
    - Weight: 125 kg



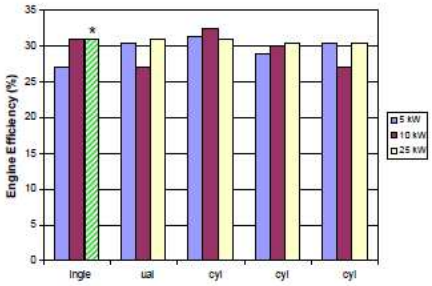


Figure 4. Engine Performance Estimates. (*CSSE estimation [1])

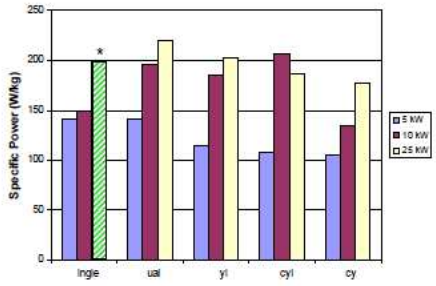


Figure 5. Specific power of engines. (*CSSE estimation [1])

Modern Steam Engines (Closed Cycle)

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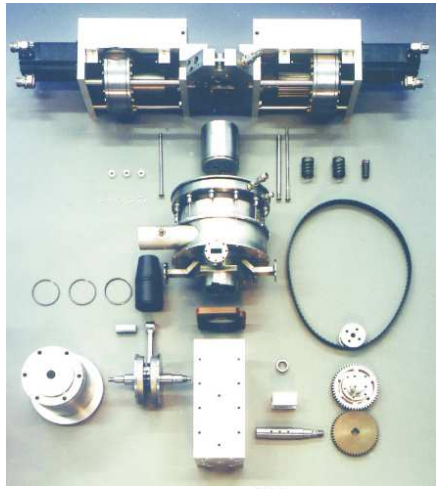
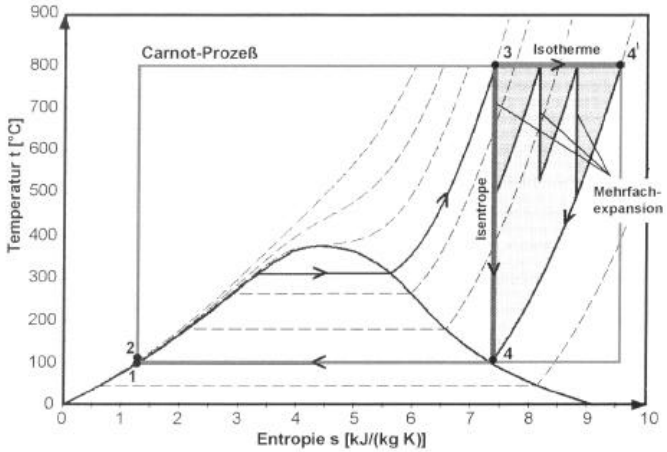
- IAV GmbH (Berlin)
  - Modified more isothermal process
  - Steam: 500°C / 50 bar
  - Efficiency: 23%



Zylinderzahl:	3
Hubraum:	992 cm^3
Bohrung:	90 mm
Hub:	52 mm
max. Brennerleistung – Brenner A: 3 x 36 kW: – Brenner B: 3 x 36 kW:	 108 kW 108 kW
Nennleistung:	50 kW
Nenndrehzahl:	2 000/min
Maximaldrehzahl:	2 500/min
Nenn-Drehmoment:	300 Nm
Max-Drehmoment (Überlastbetrieb):	500 Nm
Drehzahlbereich des Nenndrehmomentes:	200 –1500/min

- ENGINION (Berlin)
  - Efficiency: ~20%
  - Output:6 kWe
  - Weight: 32 kg



Modern Steam Engines (Closed Cycle)

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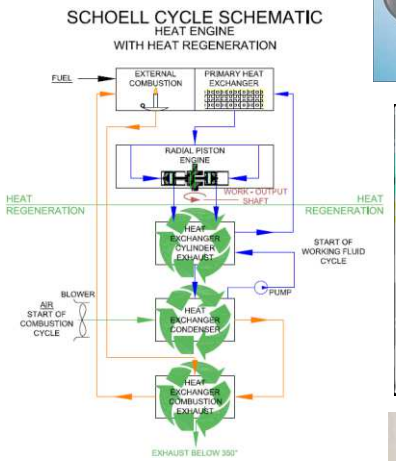
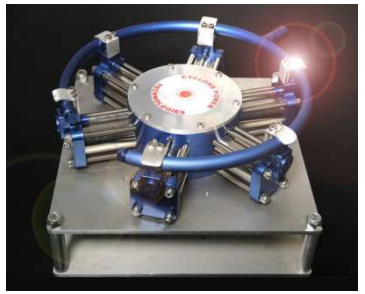
Self Powered LENR Electric Vehicles

- Cyclone Power Technologies (Florida)
  - **Cyclone Mark IV**:
    - Schoell cycle (modified Rankine cycle)
    - Efficiency: > 30%
    - Max Output: up to 70 kW (100hp)

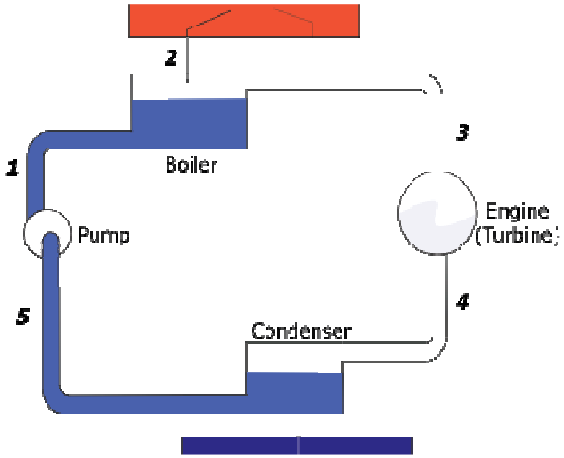


  - **Cyclone WHE** (Waste Heat Engine):
    - Rankine cycle
    - Efficiency: 12%
    - Input Temperature: 315°C (600°F)
    - Output: 10 kWe
    - Weight: 9kg + condenser + alternator



Super CO2 Turbine (Closed Cycle)

- Infinity Turbine LLC (Wisconsin)
  - IT10Super CO2
  - Modified ORC turbo-generator (Organic Rankine Cycle)
  - Output: 10 to 60 kWe
  - Efficiency: ~ 30 - 40%
  - Working temperature 140°C
  - Working pressure: 140 bar



iCar Gen 2 Example 1

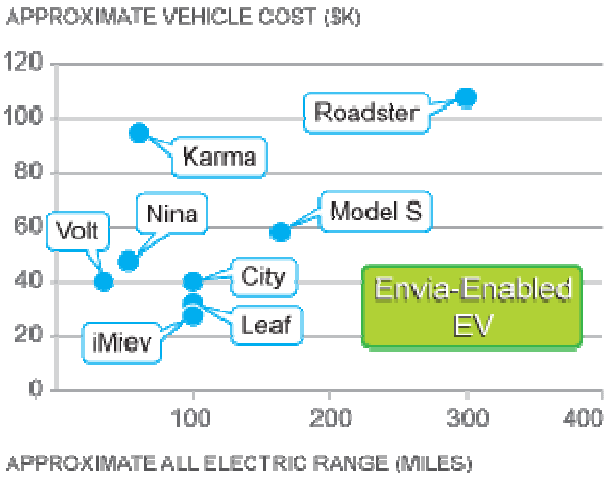
- Example: Tesla Model S
- Battery Capacity: 40 kWh
- Electrical Motor Consumption at 100 km/h: 17.0 kWh / 100 km
- Electrical Motor Consumption at 50 km/h: 11.5 kWh / 100 km
- Electrical Power Production: 8.0 kWh/h
- Overall Power Consumption at 100 km/h : 9.0 kWh
- Overall Power Consumption at 100 km/h : 3.5 kWh
- Max Range at 50 km/h: ~1140 km (~ 23 hours)
- Max Range at 100 km/h: ~ 440 km
- Range Recharging Rate: > 47 km per hour

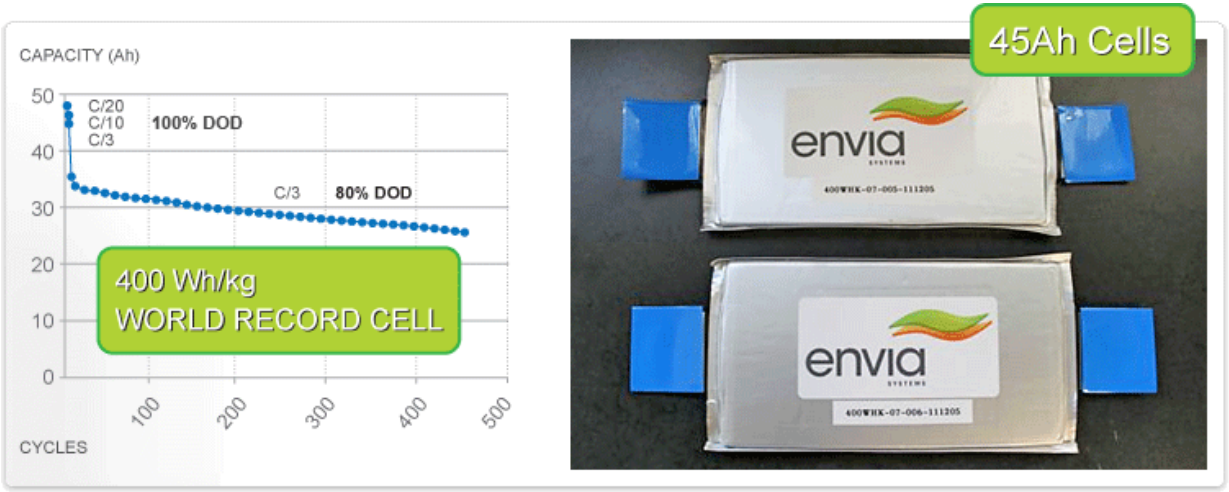
iCar Gen 2 Example 2

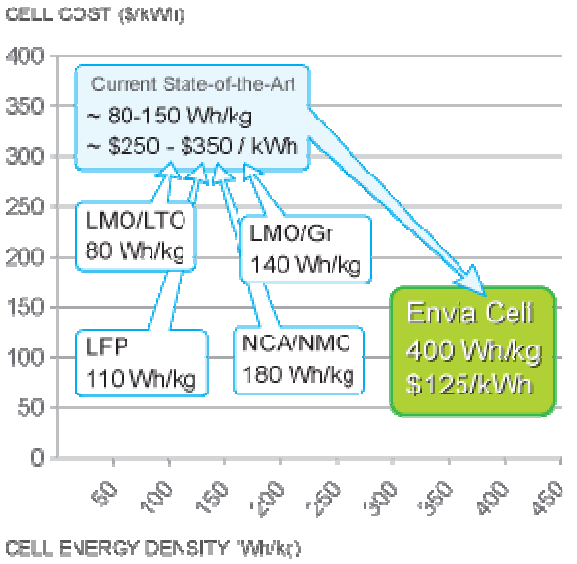
- Example: Renault Zoé
- Battery Capacity: 22 kWh
- Electrical Motor Consumption: 11.0 kWh / 100 km
- Electrical Power Production: 8.0 kWh/h
- Overall Power Consumption at 100 km/h : 3.0 kWh
- Max Range under 70 km/h: unlimited
- Max Range at 100 km/h: ~ 700 km
- Range Recharging Rate: > 72 km per hour

New Generation of Battery

- Envia Li-ion battery
  - High capacity nanostrucutred anode/cathode
  - Higher voltage electrolyte (5.2V)
- Higher specific energy: 400Wh/kg
  - Lighter electric vehicles
- Lower cost: $125/kWh
  - Affordable electric vehicles







iCar Gen 3

3rd Generation of the Ideal Car

Maintenance Free ZEV

iCar Gen 3

LENR *Cars*
Self Powered LENR Electric Vehicles

- MFZEV: « Maintenance Free Zero Emission Vehicle »
- Better thermoelectric conversion efficiency
  - thermoelectric converter embedded around LENR generator
  - based on patent pending electrochemical process
  - almost solid-state conversion technology ⇦ low maintenance
  - expected thermoelectric conversion efficiency: > 40%
  - expected overall conversion efficiency: > 25%
  - on-demand LENR generator(s): ~ 60 kW_T (6x 10 kW)
  - smaller battery energy buffer: ~ 10 kWh
  - available electrical output for recharge: > 15 kW_e

iCar Gen 3

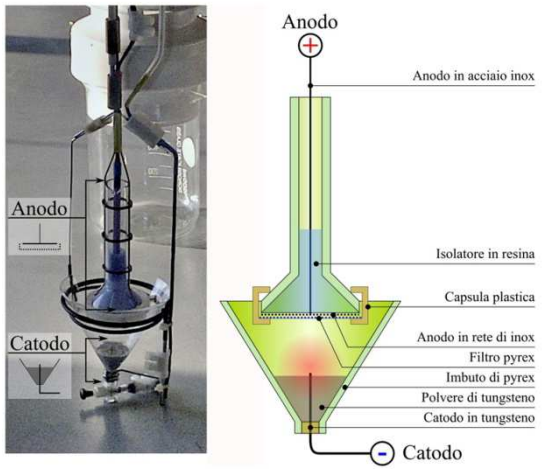
- Unlimited range:
  - More power produced (> 15 kW$_e$) than consumed (< 15 kW$_e$)
- Better battery ⇨ better energy buffer (smaller, lighter, cheaper)
- LENR generators turned on only when the vehicle is being used
- Much lighter vehicles
- Much cheaper vehicles, to buy and to use

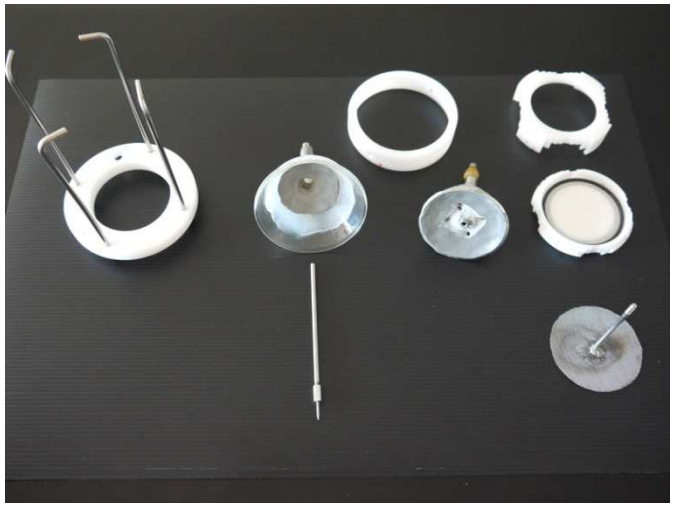
- Currently in the process of the patenting the technology

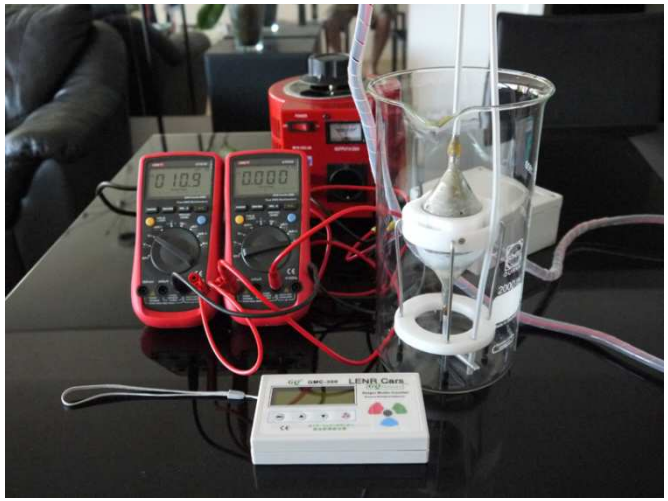
Own LENR Development

Misuno Type Anathor Cell

- Goal: demonstrate LENR to:
  - skeptical or curious scientific community
  - investors
- Based on Anathor design from IIS Pirelli (Rome)
- Hydrogen – Tungsten nano-poweder reaction
- Electroylitic hydrogen production
- Plasma inside 85° - 95°C potatium carbonate electrolyte

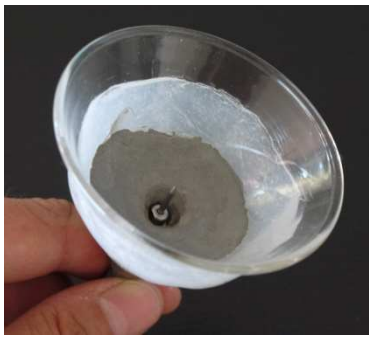






LENR Cars Anathor Cell Results

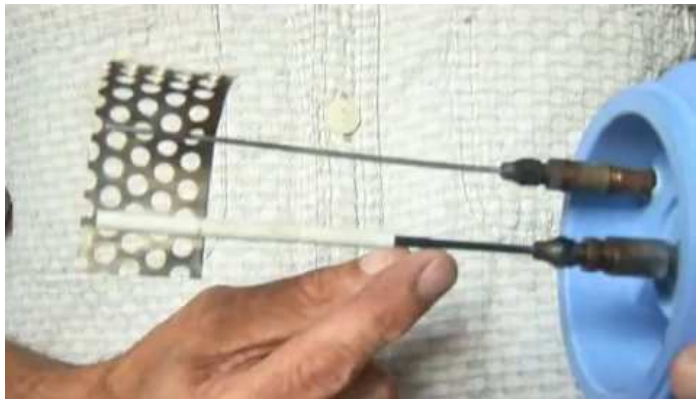
- Current Results:
  - Very preliminary experience, run once before coming here
  - Unstable plasma
  - Nano-power not confined inside the reactor chamber
  - Impossible to do measurements in these conditions



LENR Cars Anathor Cell Results

LENR Cars Anathor Cell Results

- Future Steps:
  - Improved reactor design to avoid nano-powder leakage
  - use Michael Raines' design ?
  - tune the electrodes distance
  - tune the electrolyte concentration
  - additional electrical resistance heater
  - ammeter & voltmeter logging



- Questions:
  - Is the nano-powder really needed?
  - Is it improving the COP?

Conclusion

Conclusion

LENR *Cars*
Self Powered LENR Electric Vehicles

- Results and success will be highly dependent on the availability of 10kW+ LENR generators
- EV and TEC bricks are available
- Partnerships with strong research centers will be key
- Capability to demonstrate LENR reaction is key to convince people
- Currently, LENR subject is too controversial for big automotive players to start such developement
  ⇨ opportunity for us

Q & A

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