



# Low Energy Nuclear Reactions (LENR) Phenomena and Potential Applications

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# Outline

- History
- LENR Scientific Progress
- Data: Thermal Output and Elemental Transmutations
- The LENR Entrepreneurs
- Cherokee Investment Partners/Industrial Heat /Andrea Rossi
- Replication of Rossi: Professors Parkhomov & Jiang
- Status of 6 Other Leading Entrepreneurs
- LENR Patents Granted Worldwide
- NASA LENR Position
- Summary


# History

- Early 1980's Pons & Fleischmann do research, find anomalous heat effect, but strongly correlated with hydrogen loading level (**no effect below 88% loading**).
- March 23, 1989, Univ. Admin. demands press conf. !
  - Pons and Fleischmann announce that electrochemical cells are producing more heat than can be accounted for by chemical means and speculated that nuclear reactions must be occurring.
  - Physics community complains:
    - the experiments aren't repeatable
    - there aren't any refereed papers
    - "If it's nuclear, where are the neutrons?"
  - Thousands of scientists worldwide attempted experiments—most failed because loading < 88%.
  - News media got burned – some editors may never touch story again.

# LENR Scientific Progress

## Experimental Results Since 1989

- Excess Heat >> chemistry (F&P, SRI, CL, Bockris, Storms, Energetics, ENEA, Miley, Swartz)
- $^4\text{He}$ , commensurate with excess heat (SRI, China Lake (CL), ENEA)
- Low intensity, soft X-rays (0.5-20 keV), (SRI, CL, SPAWAR, Karabut)
- Tritium Production; a species of nuclear ash (BARC, Bockris, Storms, Claytor, SPAWAR, SRI)
- CR-39 tracks suggest MeV neutron emission. (SPAWAR, BARC, Takahashi, Jones, Mizuno)
- Many nuclear transmutations,  $\Delta Z = +2, +4, +6$  (MHI, Mizuno, Bockris, Dash, SPAWAR)
- Sensitivity to radio freq & near IR stimulation (Bockris, Letts/Hagelstein, NRL).
- Emission of strong RF signals near 85 GHz (ENEA) and 1-5 MHz (NRL).

 JWK Int. & SPAWAR saw 100% reproducibility with Pd/D<sub>2</sub> co-deposition before SPAWAR effort was shut down (RASO scare), 2012.

 NASA has at least 2 teams working LENR. Positive results, still very proprietary.

 Multiple entrepreneurs now hard at work developing commercial products.

# Acceptance of LENR by Physics Community?





















- Physical Review C
- Physical Review Letters
- Journal of Physics G: Nuclear and Particle Physics
- European Physical Journal C: Particles and Fields
- European Physical Journal A: Hadrons and Nuclei
- Journal of the Physical Society of Japan
- Journal of Electroanalytical Chemistry
- Journal of Radioanalytical and Nuclear Chemistry
- Naturwissenschaften
- Physics Letters A
- Special Edition of Current Science (2x peer reviewed)

Courtesy Mosier-Boss & Forsley

*Partial List of Refereed Journals Publishing LENR Papers*

# Top Countries 2002-2012

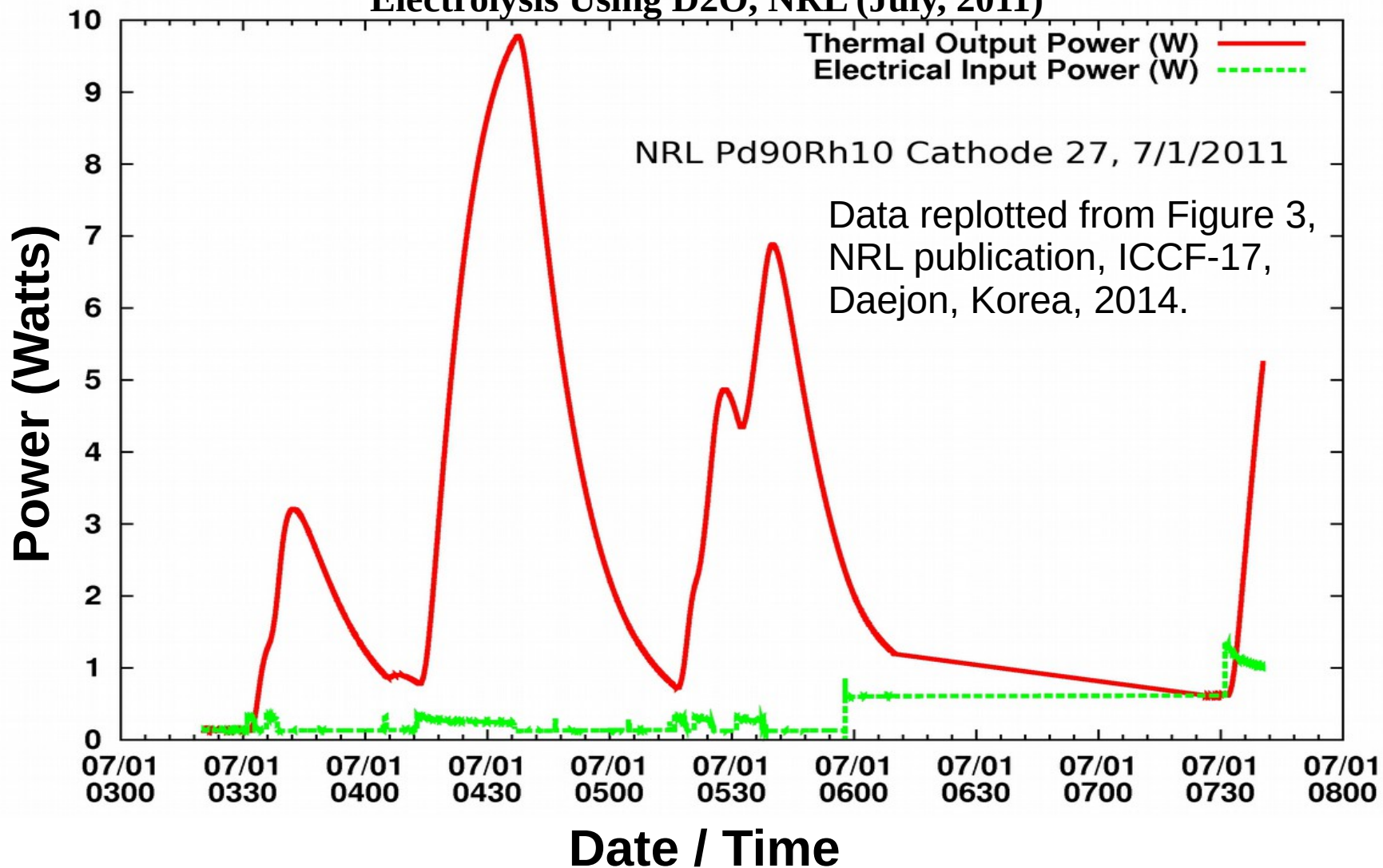
From Scopus  
&  
Web of Science

| Rank | Country        | Flag  | Trend  | Peak Year | Peak Value | Total Records | Times Cited | Hirsch Index |
|------|----------------|---|--|-----------|------------|---------------|-------------|--------------|
| 1    | United States  |    |    | 2008      | 55         | 242           | 1170        | 21           |
| 2    | Japan          |    |    | 2006      | 24         | 112           | 443         | 14           |
| 3    | Italy          |    |    | 2006,2011 | 15         | 79            | 327         | 10           |
| 4    | Russia         |    |    | 2006      | 11         | 56            | 240         | 9            |
| 5    | Germany        |    |    | 2002      | 7          | 52            | 809         | 17           |
| 6    | China          |    |    | 2008      | 9          | 40            | 285         | 9            |
| 7    | France         |    |    | 2008      | 7          | 27            | 418         | 9            |
| 8    | United Kingdom |    |    | 2008      | 5          | 25            | 352         | 9            |
| 9    | Canada         |    |    | 2008      | 6          | 22            | 314         | 10           |
| 10   | Poland         |   |   | 2008      | 5          | 22            | 346         | 13           |
| 11   | India          |  |  | 2005,2011 | 4          | 21            | 187         | 9            |
| 12   | Israel         |  |  | 2008      | 5          | 13            | 63          | 4            |

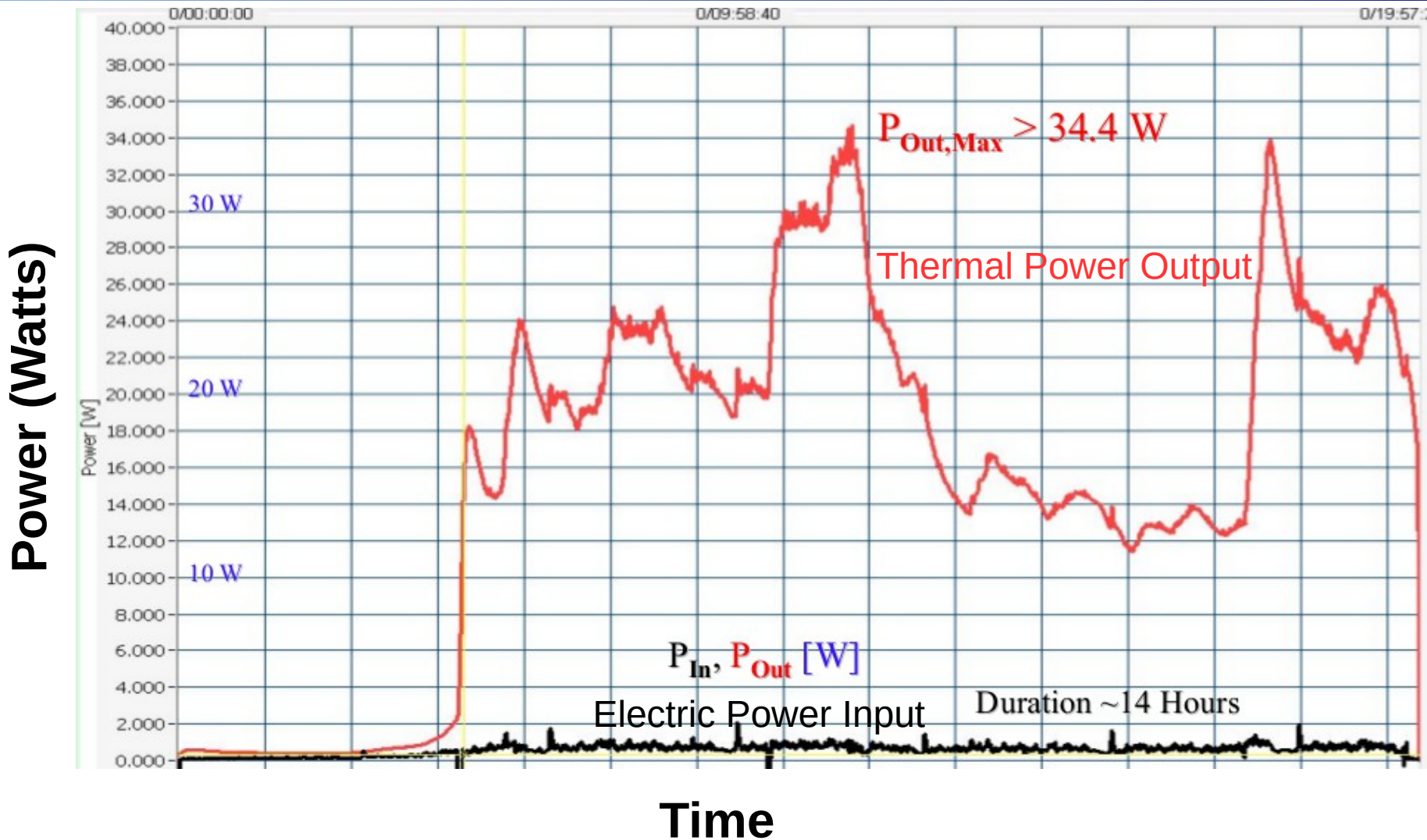
Courtesy Rayms-Keller, Rigsby, & Bingham

# NRL Saw Power Gain ~ 40

Example of Results that Rule out Errors in Input Power Measurement;  
Electrolysis Using D<sub>2</sub>O, NRL (July, 2011)



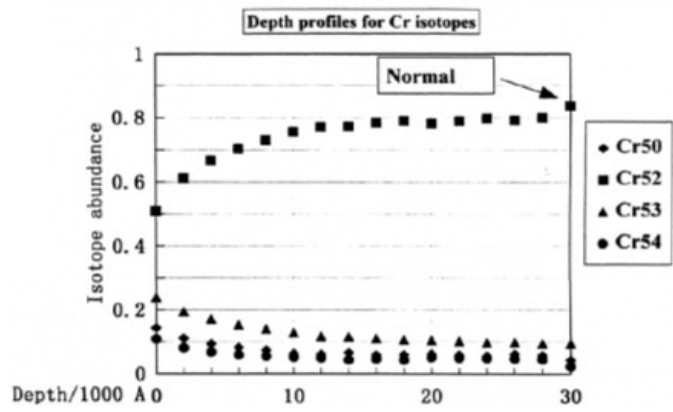
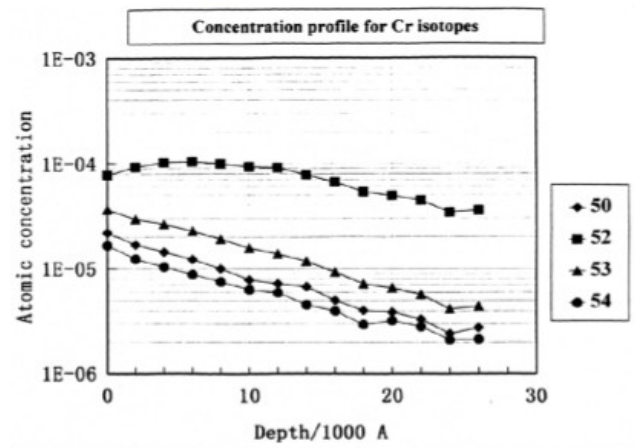
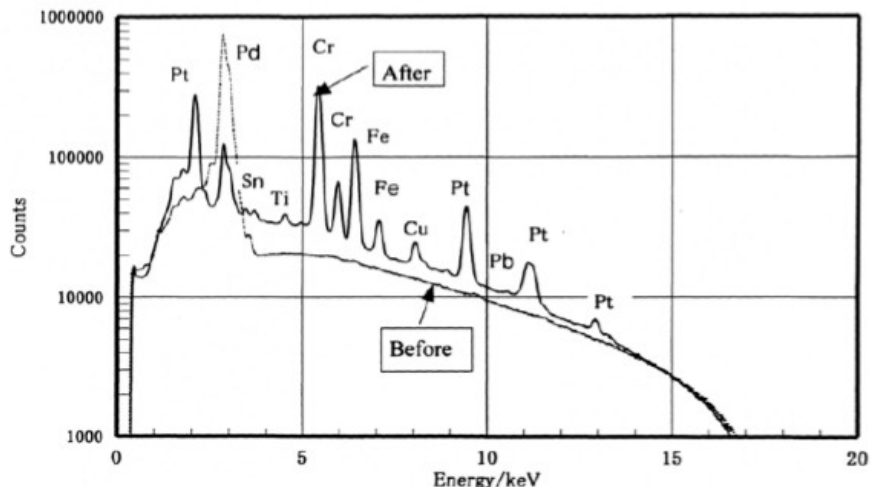
# Energetics Technologies LENR Run



Courtesy McKubre & Tanzella



# Mizuno, transmutations & isotopic anomalies

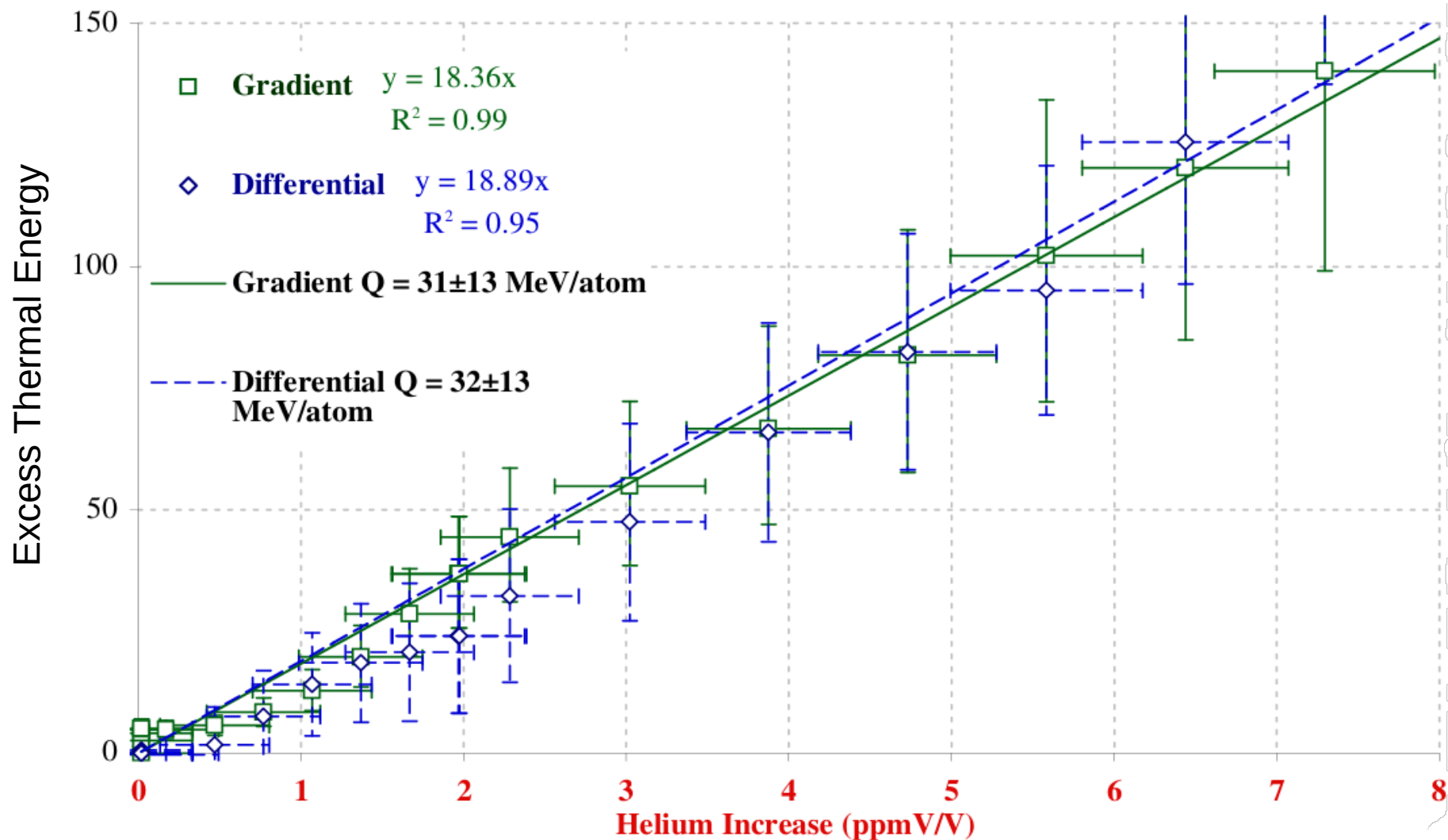


**Natural abundances: 4.3% Cr50, 84% Cr52, 9.5% Cr53, 2.4% Cr54**  
**In cathode: 14% Cr50, 51% Cr52, 2.4% Cr53, 11% Cr54**

- Used a closed, outer SS cell with a teflon inner cell
- Electrolyte was pre-electrolyzed for 7 days to remove contaminants
- Pd electrolysis ran for 32 days
- New elements accumulated in holes and cracks on the cathode which formed during electrolysis
- Some of the new elements had isotopic distributions different from natural ones. The layer 1  $\mu\text{m}$  inside showed the greatest effect.

Courtesy Mosier-Boss & Forsley

# Case: Excess Thermal Energy vs. $^4\text{He}$



Courtesy Tanzella

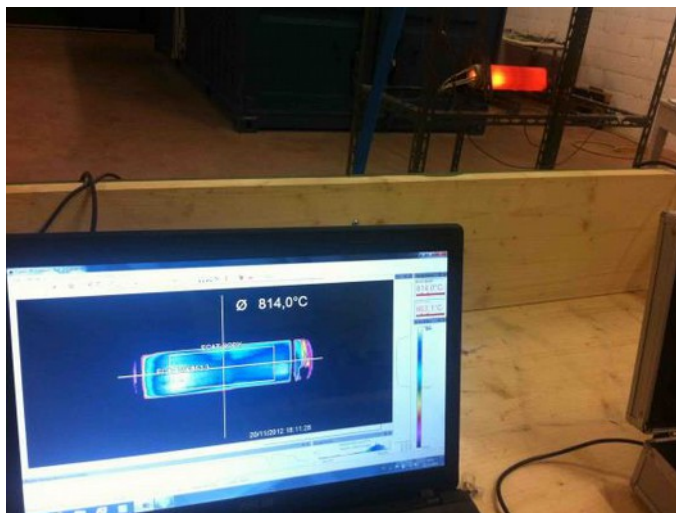
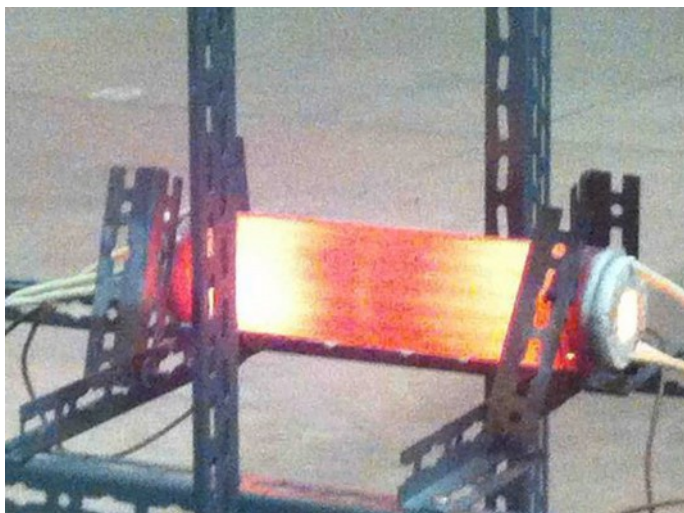


# LENR Entrepreneurs: Partial List

1. Industrial Heat (Andrea Rossi)
2. Nanortech (Mitchell Swartz)
3. Brillouin Energy (Robert Godes)
4. LENR Cars (Nicholas Chauvin)
5. Lattice Energy (Lewis Larsen)
6. Lennuco (George Miley)
7. Nichenergy (Francesco Piantelli)
8. Hope Cell Technologies (Robert Vancina)
9. Lightstone Technologies
10. Defkalion Green Technologies (seems to be defunct since Jan.)

# LENR Entrepreneur: Andrea Rossi (Андреа Росси)

- Two basic products; Ecat (10-20 kW, 200-400° C) and Hot Cat (5-10 kW, ~1200° C).
- Hot Cat tested by independent team at Lugano, Switz.
- Ran for 32 days on single, 1 gram charge of fuel powder.
- Produced ~ 1.5 MW-hours of excess thermal energy.
- Fuel had normal isotopic abundances of Li and Ni.
- Ash showed almost all  ${}^6\text{Li}$  and  ${}^{62}\text{Ni}$  => nuclear reactions.



Images from first Rossi Report

# Rossi 1 Megawatt LENR Plant

- Original version ~100 kW. Ecats in std. 20 ft. ship container.
- More recent version uses 4 250 kW reactors.
- Completed >200 days of 400 day test @ US customer factory.
- Heat is now being used by customer for mfg. operations.
- Performance report expected around Feb-Mar., 2016.
- C.O.P. ( $P_{out} / P_{in}$ ) typically varies between 20 and 80.



Images From Andrea-Rossi.com

# Prof. Alexander Parkhomov (Пархомов)

- Physics professor, Lomonosov Moscow State University.
- Thesis advisor was Andrei Sakharov (Soviet H-bomb).
- Downloaded & read Second Rossi Lugano Report.
- Used info., designed & built his own “knockoff” reactor.
- Reported COP in 2.0-3.0 range, comparable to early Rossi.
- Parkhomov results duplicated by Prof. Songsheng Jiang (PRC).



Photograph



Normal Operation



Post-mortem Photo

# Nanortech, Inc.

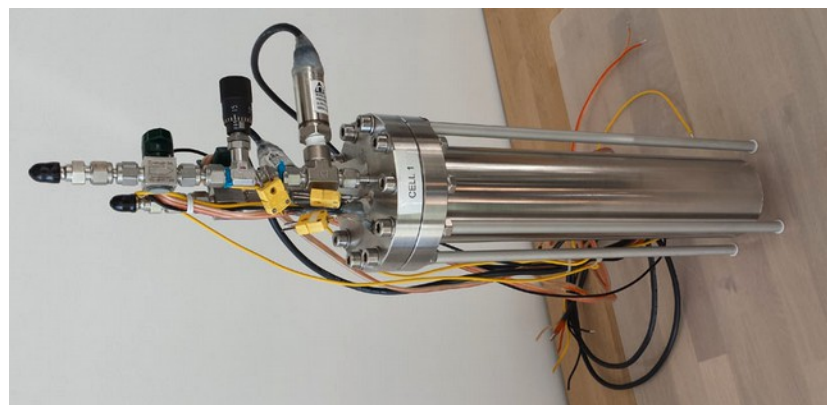
- Product: The NANOR (Dr. Mitchell Swartz)
- Structure: two terminal quantum electronic component with Pd nanoparticles embedded in  $ZrO_2$  insulating matrix, preloaded with deuterium, and energized by applying  $\sim 1$  kV between the terminals.
- Good reproducibility & controllability.
- Reports existence of optimum operating points for LENR reactors.
- Measured power densities (20 W/g) within factor of 2 of Rossi.
- Has publicly demonstrated extended operation.
- Performance report expected around Feb-Mar., 2016.
- Peak C.O.P. ( $P_{out}/P_{in}$ ) = 22-80 (JCMNS **15**, pgs. 66-80).
- Source: [ecat-thenewfire.com](http://ecat-thenewfire.com), 7/2/2015.

- Products: WET™ boiler, Hydrogen Hot Tube™ (Robert Godes)
- Basis: nickel catalyst + hydrogen + electronic excitation causes controlled electron capture reaction, forming  $^4\text{He}$  and releasing thermal energy.
- Proposed mechanism: heavy electron is captured by hydrogen nucleus, converting it into a neutron.....
- Some similarities to W-L, but also significant differences.
- Business target market: industrial boiler replacement market.
- Good reproducibility & controllability.
- Source: Brillouin Website: [brillouinenergy.com](http://brillouinenergy.com)



# LENR Cars, Inc.

- Product: LENR Fuel Cell (Mr. Nicholas Chauvin) – to be used in powering electric vehicles (cars, boats, trains, even aircraft).
- Structure: LENR reactor generates large quantities of heat, converted to electricity via free piston Stirling generator or super-critical CO<sub>2</sub> microturbine.
- Such generators are not highly efficient, but LENR power density compensates for this limitation many times over.
- Predicted range per fuel charge: 30,000 km. in electric car.
- Source: lenr-cars.com, 8/23/2015.



- Proposed Products: Thermal generators for cars (Lewis Larsen)
- Basis: Widom-Larsen Theory; surface plasmon polariton accelerates electron, electroweak reaction causes absorption by hydrogen nucleus, creating low momentum neutron, easily captured, leading to further nuclear reactions.
- Source: [slideshare.net/lewisglarsen](https://www.slideshare.net/lewisglarsen)
- Aspects of Widom-Larsen Theory:
  1. Does not require Strong Force interaction.
  2. Electroweak interaction uses collective effects of lattice (plasmon).
  3. Slow neutron thereby created is not repelled by Coulomb Force.
  4. Theory has both strong proponents & critics.
  5. Proponents include NASA Langley (Dennis Bushnell / Joe Zawodny).
  6. Critics include most of the other LENR theorists.

# Lenuco, Inc.

- Products: still in development (George Miley & team)
- Miley has support of Dept. of Nuclear, Plasma, & Radiological Engineering, University of Illinois, Urbana/Champaign.
- Basis: Gas loading & deloading to/from “alloy nanoparticles.”
- Materials progress: Team understands pure metals don't work very well as host lattices – also shown by NRL.
- Team has shown value of “nanoparticles,” however output drops when particles aggregate (also shown by NRL).
- Swartz, Arata, & others found that embedding nanoparticles in insulating matrix of  $ZrO_2$  eliminates problem of aggregation.
- Report large heat pulses during gas loading / unloading.
- Consistent with flux initiating superoscillations (Ukrainians).
- Source: e-catworld.com 8/21/2015.

# Nichenergy, Inc.

- Products: still in development (Francesco Piantelli)
- Piantelli has support of Dept. of Physics, University of Siena.
- Basis: Hydrogen is loaded into specially-prepared wires. Then electrical current passed through wires, yielding excess heat.
- Piantelli worked with Sergio Focardi & might have been the person who originally inspired Andrea Rossi.
- Piantelli was granted EU patent for LENR generator.
- Nichenergy believed to be close to commercializing product.
- Source: peswiki.com 8/22/2014.



# LENR Patents Granted Worldwide

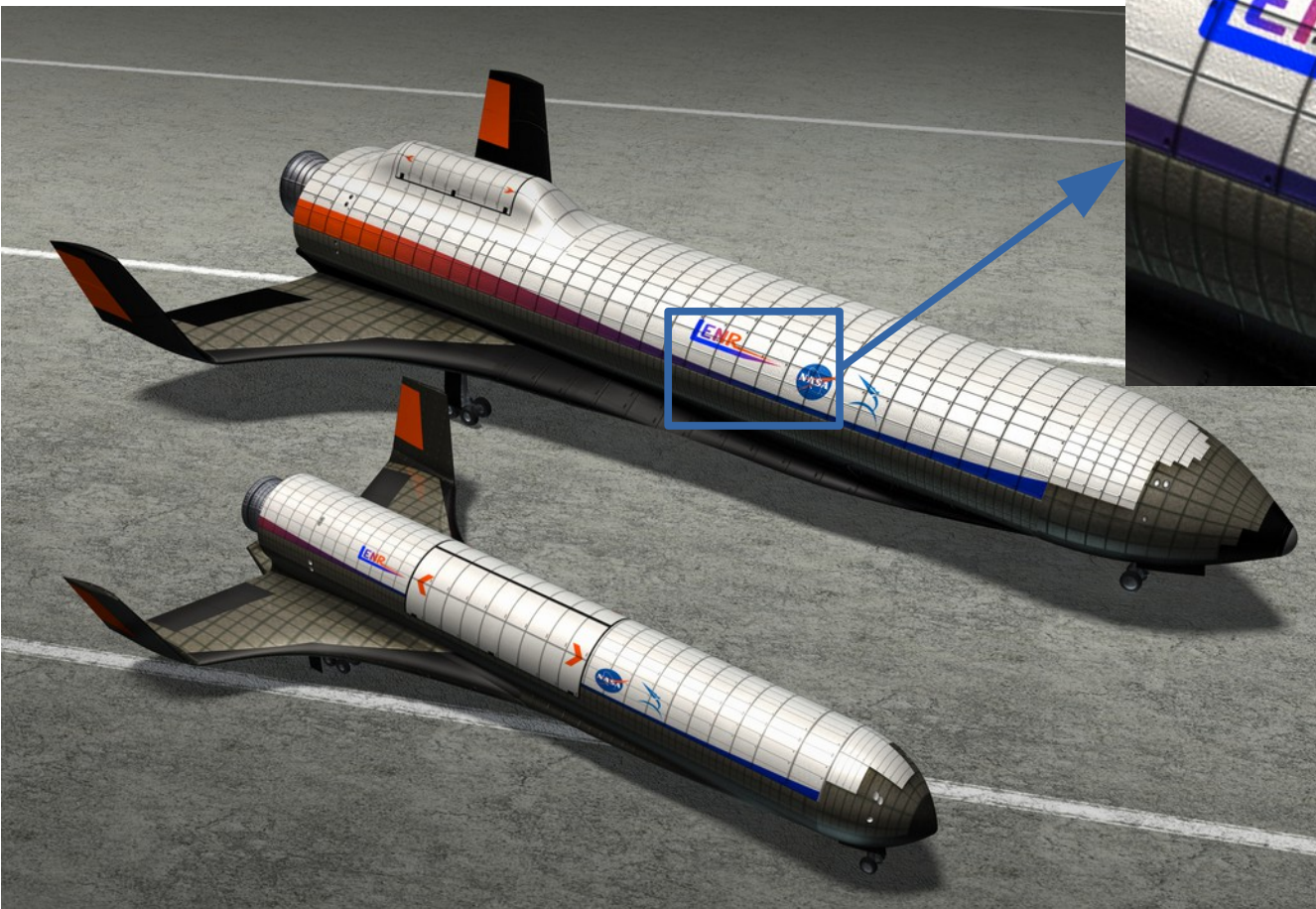
| Title  | Asignee                   | Gr. Date   | Locale |
|--|---------------------------|------------|--------|
| "Fluid Heater"                                     | Rossi, Andrea             | 8/25/2015  | USA    |
| "Nuclide transmutation device... & Method"         | Mitsubishi                | 12/4/2014  | EU     |
| "Enhanced alpha particle emitter"                  | Brown, Cravens,<br>Taylor | 8/12/2014  | USA    |
| "Power units based on dislocation site techniques" | Npl. (Miley)              | 12/10/2013 | USA    |
| "Ceramic element"                                  | Brown et al.              | 7/16/2013  | USA    |
| "System and method for generating particles"       | JWK / Navy                | 4/16/2013  | USA    |
| "Method for producing energy & apparatus therefor" | Piantelli et al.          | 1/16/2013  | EU     |
| "Method for producing thermal energy"              | Purratio Ag.              | 8/15/2012  | CN     |
| "Pulsed LENR power generators"                     | Energetics                | 5/4/2011   | EU     |
| "Power producing device"                           | Kirkinskii et al.         | 12/23/2009 | EU     |

Sources: e-catworld.com and gbgoble.kinja.com

**Conclusion: The patent door is no longer slammed shut upon inventors, even in USA.**

# NASA View of LENR

⚡ Mars is just the first stop; “*Per aspera, ad astra.*”



Images from  
Spaceworks  
Engineering  
Website.

# Summary

- Low Energy Nuclear Reactions appear to be real; are probably attributable to something like nuclear fusion. BUT ...
- Presence of lattice profoundly affects results; little prompt radiation...
- Multiple labs observed excess heat, elemental transmutations, soft X-ray emission,  $^4\text{He}$  generation commensurate with heat, tritium production, occasional MeV neutron emission, and RF emission in the HF and mm wave bands.
- SPAWAR, & JWK Internat. and others all observed 100% repeatability.
- Rossi Hotcat tested by 3<sup>rd</sup> party academic group;  $1.5 \times 10^6$  Watt-hours excess thermal energy over 32 day continuous run + isotope shifts.
- Hotcat has been duplicated by Profs. A. Parkhomov (Moscow) & Jiang\* (PRC).
- Commercial products (1 MW plant) now being tested, customer location.
- E-cats in 1 MW plant were still running on initial fuel charge at 4 months, COP varies between 20 and 80 in self-sustain mode.
- Multiple entrepreneurs now developing products for market.
- Ten LENR patents actually granted worldwide during past 5 years, 5 by USPTO.
- Plans exist to build LENR propulsion systems into vehicles for sale to public.
- NASA plans to use LENR thrusters in deep-space probes.

\*Professor Jiang is also affiliated with China Institute of Atomic Energy, Beijing.