Public Perception of Nuclear Energy

Julio Vergara Aimone

LAS-ANS, Rio de Janeiro, June 22nd, 2016
Opinion about NE in Chile → relevant?

The context and the perception.

Wishes and fears in technology.

Spock: It is not logic, Captain Kirk!

Can we do something sound about it?
The Context
Do we know what energy (1st principles) is?

- It is about repulsion (EM, heat, movement)
- It is about matter breakout (fusion, bosons)
- It is about transformation (m $\rightarrow$ KE)
- It is about damage (muons, interactions)
- It is a consequence, a result (not planned)

So energy is restless, not steady nor calm...
Energy (different forms and fuels) has given us a service in recent centuries, it has been crucial for developing our society, allow our wellness and prosperity (true and apparent).

However, it is turning against us, with political problems (international friction), environmental pollution (health), accidents, weather shifts (heat waves), anticipating midterm disturbance (water availability, climate change) → social strain.
## The Context

### Once upon a time, not so far ago

<table>
<thead>
<tr>
<th>Context:</th>
<th>Global War on Terrorism (comex 11-09-01).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Cause:</td>
<td>WMD (unsupported by UNMOVIC). Possible support to Osama Bin Laden (WTC).</td>
</tr>
<tr>
<td>Real Cause:</td>
<td>Stop Saddam Hussein’s dictatorship. Avoid effects over energy resources and restore peace in the Middle East (restored?).</td>
</tr>
<tr>
<td>Outcome:</td>
<td>60.000 dead, 120.000 wounded. Humanitarian crisis &amp; material losses. Not yet settled.</td>
</tr>
</tbody>
</table>
The Context

Health effects by fossil fuel combustion

Are you looking for another Replicant, Blade Runner?
Increasing accidents in the energy sector

- Cosmo Oil Co. Refinery in Ichihara
- Deepwater Horizon Platform (5)
- Fukushima Dai-ichi Power Plant
- Soma Coal Mine, Turkey (301)
Increasing accidents in the energy sector

- Natural disasters
- Energy related accidents
- Other accidents

The Context

Energie-Spiegel No. 13 / May 2005
The Context

Sharp population and energy use growth

Primary Energy (EJ) vs Million Inhabitants (#)

- 1800: ~1000 MM
- 2000: ~6000 MM
- 2016: ~7400 M#
- ~550 EJ
- 2050: ~9000 MM

The Context
The Context

Sharp population and energy use growth

The chart illustrates the sharp population and energy use growth over time. The x-axis represents the year, starting from 1800 to 2100, with significant events such as the Industrial Revolution highlighted. The y-axis shows the primary energy (EJ) and grows exponentially, indicating a significant increase in energy consumption. The chart emphasizes the steep rise in energy use following the Industrial Revolution, showcasing the dramatic impact on the world's energy demand.
The Context

Energy emissions threatening sustainability

- Primary Energy (EJ)
- ppm CO₂

- RCP-SRES-IS92a
  - RCP8.5
  - RCP6.0
  - RCP4.5
  - RCP2.6
- SRES
  - A1T
  - A2
  - B1
  - IS92a

Measurements (ice cap drilling)

Est. RCP

Industrial Revolution

CO₂ (ppm)

EP (EJ)

Year

+5 °C
+4 °C
+3 °C
+2 °C
+1 °C
The Context

Fires by heat waves on increasingly dryer land

Australia, every couple of years
Water scarcity, i.e. 400 km north of Santiago

The Context

Today: contains about 3% of design volume. Other reservoirs in the area may also apply.

La Paloma reservoir (1968) 3000 ha, 750 MM m³
The Context

Antarctica and Greenland loosing water?

$\sim 30$ (-37 – 97)  
$\sim 147$ (72 – 221)  
1992-01  
2002-11  
$\sim 34$ (-6 – 74)  
$\sim 215$ (157 – 274)  
Gt $H_2O/y$
Antarctica and Greenland loosing water

- 1992-01: ~34 (-6 – 74) Gt H₂O/y

Moulin and ice sheet breakup in Greenland → may affect the Atlantic THC
Current sea level is the highest in 120,000 years.

Today's sea level is the highest in 120,000 years.

The Context
A broader context: new megatrends
When Source Selection Comes
When source selection comes

This is what one may expect, as surveyed

<table>
<thead>
<tr>
<th>NUCLEAR</th>
<th>HYDRO DAM</th>
<th>NC RENEWABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large</strong></td>
<td><strong>Large</strong></td>
<td><strong>Small</strong></td>
</tr>
<tr>
<td>I would barely benefit.</td>
<td>Allow foreign capitalism</td>
<td>I might benefit from being part of it.</td>
</tr>
<tr>
<td>Big players only allowed.</td>
<td>deplete our resources.</td>
<td></td>
</tr>
<tr>
<td><strong>Powerful</strong></td>
<td><strong>Powerful</strong></td>
<td><strong>Modest</strong></td>
</tr>
<tr>
<td>Unsafe. It has exploded</td>
<td>Distorts nature. Power lines will be a scar.</td>
<td>Not a complex machine.</td>
</tr>
<tr>
<td>(as seen in CNN).</td>
<td></td>
<td>Simple to setup &amp; use.</td>
</tr>
<tr>
<td><strong>Artificial</strong></td>
<td><strong>Artificial</strong></td>
<td><strong>Natural</strong></td>
</tr>
<tr>
<td>It is synthetic, man-made,</td>
<td>This was not developed by nature.</td>
<td>Wind is natural. It is there. Use it.</td>
</tr>
<tr>
<td>elaborated.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dirty</strong></td>
<td><strong>Dirty</strong></td>
<td><strong>Clean</strong></td>
</tr>
<tr>
<td>It is synthetic, man-made,</td>
<td>Replaces a wild forest by concrete and steel.</td>
<td>Wind helps clean the environment.</td>
</tr>
<tr>
<td>elaborated.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most of us would use a logic approach in technology selection, for climate change mitigation. Nuclear technology would rank at the top level. But, this is not what occurs. The society is tied to fossils and builds RE for its consciousness. Nuclear engineers need to be psycho-PR-socio-logists before practicing. We demand to better comprehend our society, policy and markets.
When source selection comes, we assume everybody understands risks.
Issues needed to be understood for acceptance:

- Radiation safety
- Evacuation areas
- Nuclear waste (SNF)
- Fuel supply
- Capital cost
- Proliferation
- LNT deadlock

We do not communicate well. Images do it for us

When source selection comes

“So-called nuclear engineering expert”
“ex NRC staff”
Brilliant at communicating nuclear fear

Arnie Gundersen
Chief Nuclear Engineer
Fairewinds Associates Inc
www.fairewinds.com
We do not communicate well. Images do it for us.
25% of us fear something or sweat when flying.

Based on the chart, what is the right conclusion? What is the actual conclusion? I will come back.
Understanding the Problem
Understanding the Problem

We all have opinions and perceptions

The perception

Trump
Anarquist
Model
Conservative

The reality

FIFA
Government
Entrepreneur
Environmentalist

The interests

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Understanding the Problem

We all have opinions and perceptions

The perception

The reality

The filters

Movies  Accountant
Sociologist  Designer
Biologist  Engineer
Lawyer  Athlete
The reality
The subjective
Ideas, experiences, visions, beliefs
The perception
The reality
The subjective
Understanding the Problem

The fact: reality and perception do not match

The perception

Ideas, experiences, visions, beliefs
Tuned by career and degree of knowledge

The reality

The subjective

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How does these people communicate?

Understanding the Problem
Energy needs to be socially accepted today

Understanding the Problem

Socio-political Acceptance
- General public
- Stakeholders
- Politicians

Community Acceptance
- Affected population
- Local groups
- Local authorities

Market Acceptance
- Contract viability
- Banks and investors

The technology
The applications
The consequences

Adapted from Rolf Wüstenhagen et al (2007)
Understanding the Problem

Energy needs to be socially accepted today

Santiago 2014: (Alto Maipo, 531 MW)

Copiapó 2010: (Castilla, 2256 MW)

Santiago 2011: (Signing of a US security protocol)

Curacautín 2015: (Minihydro, 3 MW)

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Energy needs to be socially accepted today

Santiago 2011
(Hidroaysén, 2750 MW)

Chiloé 2015
(Wind farm, Chiloé, 100 MW)

San Pedro 2009
(geothermal, El Tatio, 40 MW)

La Serena 2012
(thermal, Barrancones, 540 MW)

Understanding the Problem
Understanding the Problem

Several new terms linked to energy

Biodiversity  GHG  Renewable source
Climate Change  Adaptation  Exergy
IPCC  Wind  Fossil
Dependency  Accidents  Deterrence
Hybrid  COP  Sustainability
RCP2.6  Non renewable  Security
Negotiation  Ethics  Conservation
Prosperity  Commerce  Wellness
Risks  Nuclear energy  Geopolitics
Wellness  Hydropower  Electricity
Endurance  Storage  Liability
Limits to Growth  Non renewable  Geopolitics
Reality versus Perception
### Reality versus Perception

**A Government study requested to UC (before F1)**

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Gas</th>
<th>Wind</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Cleanest</td>
<td>0.4</td>
<td>3.7</td>
<td>32.4</td>
<td>12.0</td>
<td>1.1</td>
<td>48.3</td>
</tr>
<tr>
<td>The one delivering the most dangerous</td>
<td>2.1</td>
<td>19.6</td>
<td>7.9</td>
<td>37.4</td>
<td>6.2</td>
<td>21.2</td>
</tr>
<tr>
<td>The most dangerous</td>
<td>17.8</td>
<td>14.3</td>
<td>0.9</td>
<td>3.9</td>
<td>59.0</td>
<td>1.5</td>
</tr>
<tr>
<td>The least expensive</td>
<td>29.3</td>
<td>6.7</td>
<td>13.3</td>
<td>8.4</td>
<td>2.1</td>
<td>33.7</td>
</tr>
<tr>
<td>The most powerful</td>
<td>1.7</td>
<td>8.3</td>
<td>1.6</td>
<td>31.1</td>
<td>36.9</td>
<td>12.7</td>
</tr>
</tbody>
</table>
Reality versus Perception

Not exactly what people perceive
Reality versus Perception

Generation costs in different regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Nuclear</th>
<th>Coal</th>
<th>Gas</th>
<th>Offwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. America</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asia Pacific</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Nuclear</th>
<th>Coal</th>
<th>Gas</th>
<th>Offwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. America</td>
<td>10.0</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Europe</td>
<td>15.0</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>20.0</td>
<td>4.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

The least expensive:
- N. America: Coal
- Europe: Gas
- Asia Pacific: Nuclear

The most powerful:
- N. America: Nuclear
- Europe: Gas
- Asia Pacific: Nuclear

The Cleanest:
- N. America: Nuclear
- Europe: Gas
- Asia Pacific: Nuclear

Mills/kWh @10% OCDE 2010

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Reality versus Perception

Nuclear fission -by far- the densest

20 - 50 \( W_p/m^2 \)

50,000 - 100,000 \( W_e/m^2 \)
Number of Fatalities per GW-yr (1969-1996, including Fukushima Dai-ichi)

- **Coal**: Mean Value (1969-1986) = 17.8, The most dangerous = 32.4
- **Gas**: Mean Value (1969-1986) = 14.3, The most dangerous = 12.0
- **Wind**: Mean Value (1969-1986) = 0.9, The most dangerous = 0.3
- **Hydro**: Mean Value (1969-1986) = 3.9, The most dangerous = 33.7
- **Nuclear**: Mean Value (1969-1986) = 59.0, The most dangerous = 60.0
- **Solar**: Mean Value (1969-1986) = 1.5, The most dangerous = 3.0

**Reality versus Perception**

Nuclear fission not the most dangerous

The Cleanest: Coal, Gas, Wind, Hydro, Solar

The one delivering the most powerful: Coal, Gas, Nuclear, Solar

The least expensive: Coal, Gas, Solar

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Reality versus Perception

Nuclear fission not the most dangerous

Immediate Accident Fatalities (1969-1996, including Fukushima Dai-ichi)

Coal  Oil  Natural Gas  Hydropower  LPG Gas  Nuclear

Max. fatalities (1969-1996)
Min. fatalities (1969-1986)
Fritzsche (1969-1986)

Severe Accidents in the Energy Sector, PSI, 1998

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Reality versus Perception

Nuclear fission not the most dangerous

Severe Accidents in the Energy Sector, PSI, 2005

Frequency (#Fatalities/GWy > N)

Total OECD

Severe Accidents in the Energy Sector, PSI, 2005

Total non OECD

Nuclear (latent fatalities by PRA)

Fatalities N

Fatalities N
A few recent examples of energy accidents

- **2010, Upper Big Branch Mine, W. Virginia** (38)
- **2010, Pike River Mine, New Zealand** (29)
- **2010, Anacortes Refinery, USA** (10)
- **2010, San Bruno Gaspipe, California** (08)
- **2010, Raspadskaya Mine, Kemerovo, Russia** (66)
- **2010, GNCC Plant, Connecticut, USA** (05)
- **2010, Deepwater Horizon Platform** (11)
- **2010, Dosquebradas Gaspipe, Colombia** (39)
- **2011, Coal Mine Well, México** (14)
- **2011, Gales Refinery, Great Britain** (04)
# Reality versus Perception

A few recent examples of energy accidents:

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Sorange Coal Mine, Pakistan</td>
<td>(45)</td>
</tr>
<tr>
<td>2012</td>
<td>Amuay Refinery, Venezuela</td>
<td>(41)</td>
</tr>
<tr>
<td>2012</td>
<td>Pemex Gas Plant, Mexico</td>
<td>(26)</td>
</tr>
<tr>
<td>2012</td>
<td>Fuel Truck Explosion, Nigeria</td>
<td>(121)</td>
</tr>
<tr>
<td>2012</td>
<td>Damp gas in Múzquiz, Mexico</td>
<td>(07)</td>
</tr>
<tr>
<td>2012</td>
<td>Panzhihua Coal Mine, Sichuan, China</td>
<td>(41)</td>
</tr>
<tr>
<td>2013</td>
<td>Vorkutinskaya Mine Explosion, Russia</td>
<td>(18)</td>
</tr>
<tr>
<td>2013</td>
<td>Crude Oil Train, Quebec, Canada</td>
<td>(47)</td>
</tr>
<tr>
<td>2014</td>
<td>Soma Mine Explosion, Turkey</td>
<td>(301)</td>
</tr>
<tr>
<td>2014</td>
<td>Gas Explosion in Kaohsiung, Taiwan</td>
<td>(30)</td>
</tr>
</tbody>
</table>
Reality versus Perception

More people died due to the evacuation
2011: Ichihara y Chiba, Japón. Explosiones de refinerías por el terremoto y tsunami de Tohōku.
Reality versus Perception

Energy accidents with less media coverage

2011, Cosmo Oil Co. in Ichihara, Japan

2013

10 days later
Reality versus Perception

Energy accidents with less media coverage

2011, PCSC Coal Power Plant, Haramachi, Japan,
Reality versus Perception

Energy accidents with less media coverage

2013, Lac-Mégantic, Quebec, Canada. Runaway train without a train driver.
Conclusions
I do not have a clue: logic does not help much. Not sure if the nuclear industry understands the social patterns. Our society is comfortable with an ipad scale and vendors sell 1-2 GW-units.

Teach engineers and others. Get into business and social sciences schools. Study psychology.

Need to educate about energy and to put risks & benefits, truth & myths, in proper balance.
Conclusions

Master of Energy Engineering with nuclear content

QS rank #167
Conclusions

Energy Diplomas also offered, incl. Nuclear Power
Meeting renewable and nuclear energy is one initiative. But that may better help the industry, not the environment nor the future of society.

Need to integrate the fossil and the biomass industries to help mitigate their externalities with nuclear energy products and techniques.

Perhaps these industries are better partners for sustainable energy. RE (not hydro) has replaced less than 2%. Get into politics, get a vaccine!
Speaker: Julio Vergara Aimone

PhD, Nuclear Materials, MIT; MBA, UAI; MSc, Nuclear Engineering, MIT; MSc, Naval Architecture & Marine Engineering, MIT; MSc Materials Engineering, MIT; Naval Engineer and BSc in naval Engineering, APN.

Professor of Sustainable Energy, Nuclear Engineering, and Design, PUC; former Professor of Management of technology and Innovation, UDD & UAI.

Listed in Marquis´ “Who´s Who in the World” and “Who´s Who in Science and Engineering”. Former Consultant to the IAEA. Board Member, CCHEN. President of 2015 Latin American Section of ANS.