# Thorium and Molten Salt Reactors

## *Improving Public Knowledge and Awareness*

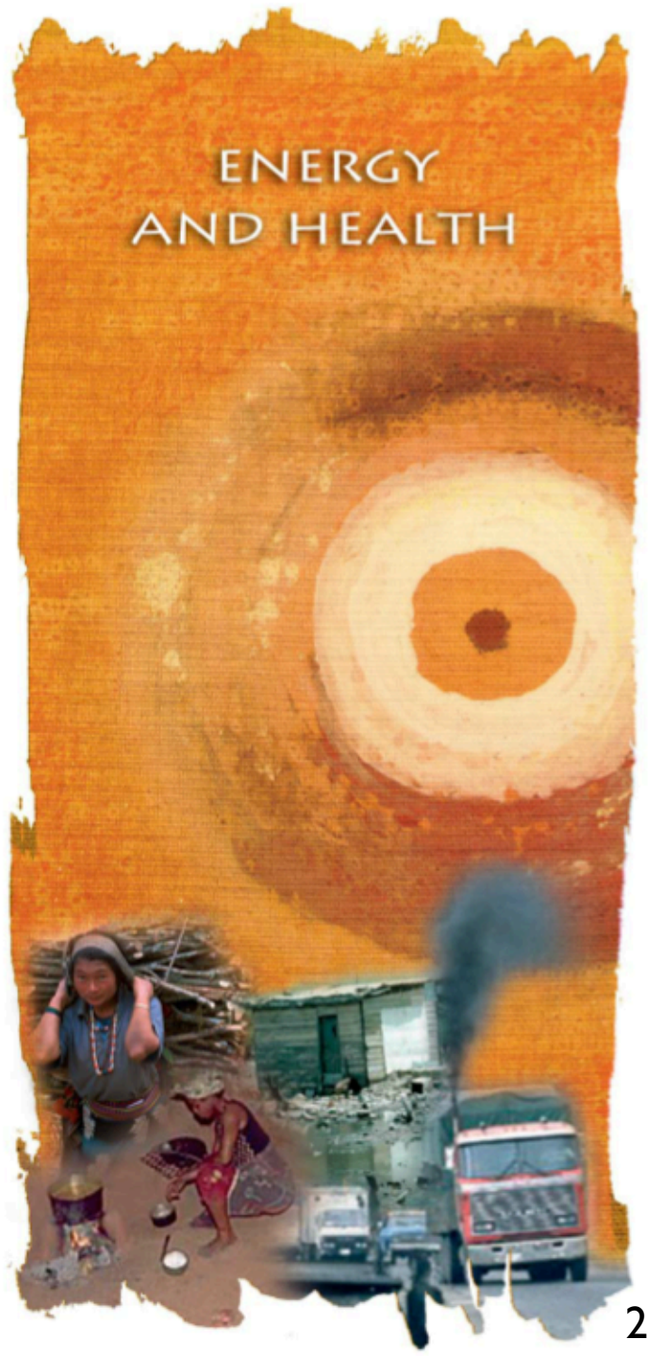
Katherine (Katie) Hudek

May 2013

# Why Is Energy Important?

A safe and abundant energy supply will benefit humanity:

- Improved food production, food storage and refrigeration
- Clean water and waste-water systems
- Production of goods and medicines
- Improved quality of life, etc.




The World Health Organization has highlighted a connection between household energy and health

- In Southeast Asia and Africa, burning dung, coal, wood, etc. for cooking and light leads to air pollution and respiratory illnesses
- See World Health Organization (http://www.who.int/indoorair/en/)

# Thorium and MSRs

- Great potential for providing safe and abundant power
- Supported by experiments at Oak Ridge National Laboratories (ORNL)
  - Led by Alvin Weinberg
    - Aircraft Reactor Experiment (ARE)
    - Molten Salt Reactor Experiment (MSRE)
- Safe, low-pressure, self-regulating, smaller quantity and shorter duration of radioactive waste, etc.

***However...***

# “Timendi causa est nescire.”

*“Fear always springs from ignorance.”*
- Ralph Waldo Emerson

Ignorance → Fear → Opposition

- *People should not sail far from shore, or they’ll fall off the edge of the world!* - nonfactual medieval belief

- *Is Thorium a naturally occurring element? No* - nonfactual claim from a LFTR opponent

*“Timendi causa est nescire.”*
*“Ignorance is the cause of fear.”*
- Seneca

# “Knowledge is Power”

Knowledge → Understanding → Support

Two Different Audiences:

- Children/Students
- Adults

# Children/Students

Promote chemistry and physics at earlier ages

- Would lead to less fear and misunderstanding when learning about nuclear power
- Use unit studies that are fun and exciting
  - I enjoyed online learning which occasionally included animations
- Traveling interactive exhibits for children's museums
- Computer games involving chemistry and/or physics

# Children/Students

In my case, I first learned about chemistry at a young age

- At age 9, wrote “Element Comics”*
- Wrote two plays* involving chemistry and physics:
  - *It’s Elementary!*
  - *The Great Electron Mystery!*

* *Samples in Appendix*

# Adults

Adults would benefit from educational materials as well:

- Materials should include basic chemistry, physics, and nuclear power information
- Multimedia presentations
- Interesting museum exhibits
- I received comments on my videos from adults seeking background information
  - I am currently creating a new video explaining chemistry fundamentals

# How I Became Interested in Th and MSRs

- Always found science to be exciting and fun!

- Have been fascinated with chemistry, physics, and radioactivity for many years

- Nuclear accident at Fukushima, Japan on March 11, 2011

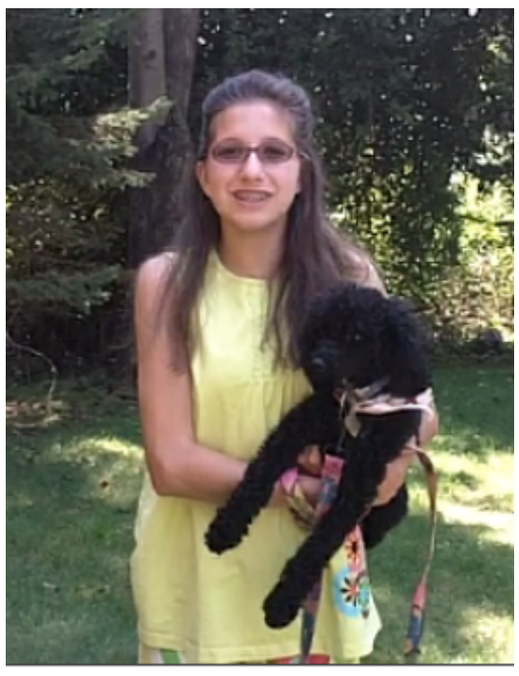
- Was inspired to pursue my science fair project:
  - *"Nuclear Energy: How Can We Make It Safer?"*

# How I Became Interested in Th and MSRs

- *"Nuclear Energy: How Can We Make It Safer?"*
  - Found information online about ORNL, MSRs, and LFTR designs
  - Excited to learn about the potential of MSRs and Thorium as a fuel!
  - Both qualitative and quantitative analyses demonstrated advantages of Thorium and MSRs over conventional high-pressure, light-water reactors of today

# How I Became Interested in Th and MSRs

- Also entered separate science video competition but limited to maximum of two minutes...
  - Not long enough!
  - But a lot of fun...
- Continued making longer videos explaining my science fair project and uploaded to Youtube
  - "KatieScienceAndArts" channel
    http://www.youtube.com/user/KatieScienceAndArts
  - Tried to portray science as exciting and fun with "Katie and Caysie Science Videos"



# Continuing Interest

Have extended my original science fair project

- Incorporated feedback and adjusted estimated transition probabilities for sudden loss of power fault condition
- Simulation models can be run with different transition probabilities - would love to have real world data to incorporate in my models
- Have since created a new simulation to model a leaks in piping fault condition
- Ran simulations and recorded new results
- More information in Appendix

# Summary

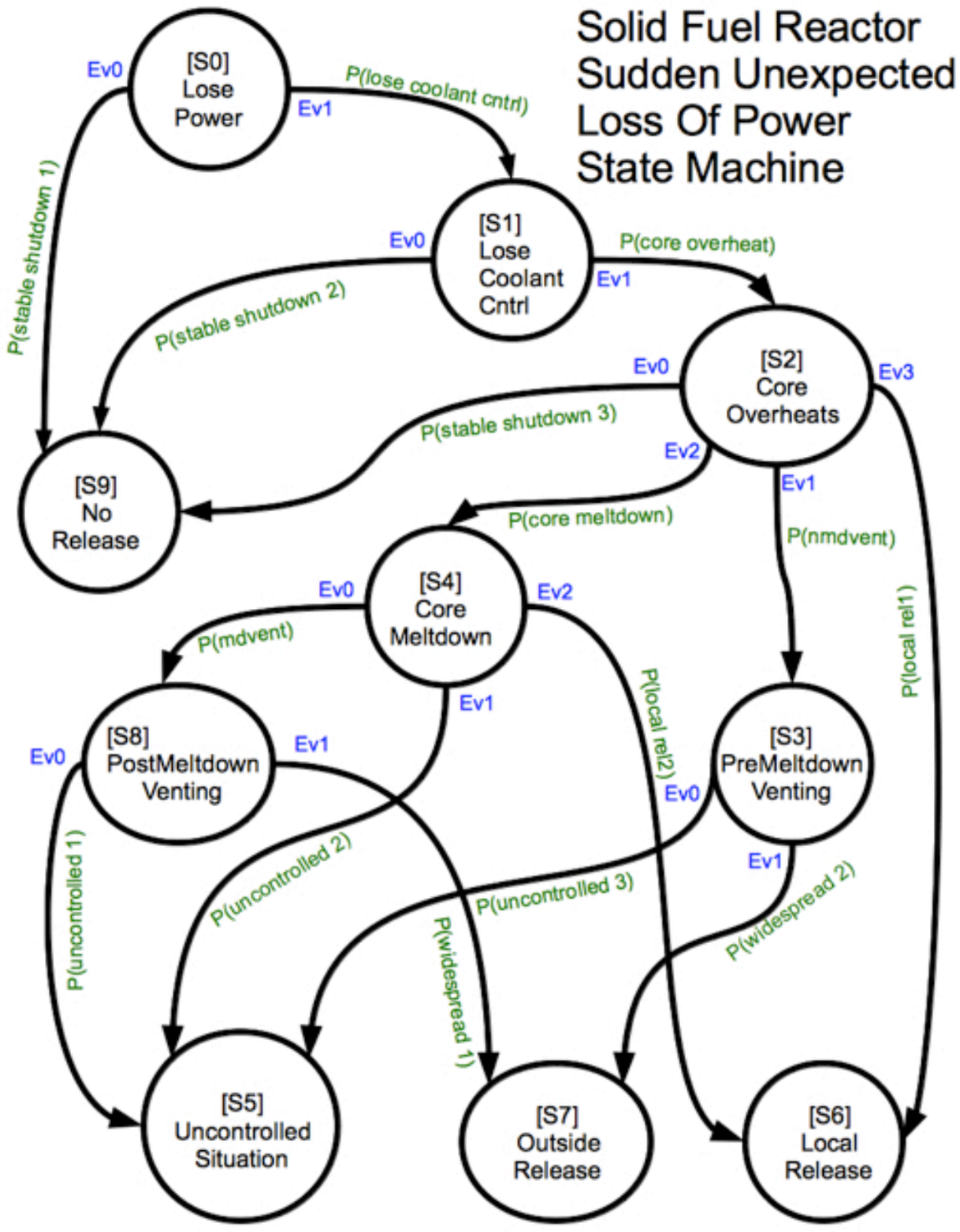
- Energy is very important to the well-being of humanity
- Thorium and MSRs are a promising technology
  - Safer reactors
  - Much less and shorter lived radioactive waste
- Ignorance ➜ Fear ➜ Opposition
- Knowledge ➜ Understanding ➜ Support
- Important to educate both children and adults
  - Fun and exciting unit studies
  - Interactive exhibits for museums
  - Multimedia presentations
- Very excited about Thorium as a fuel!

# Thank You

# Appendix

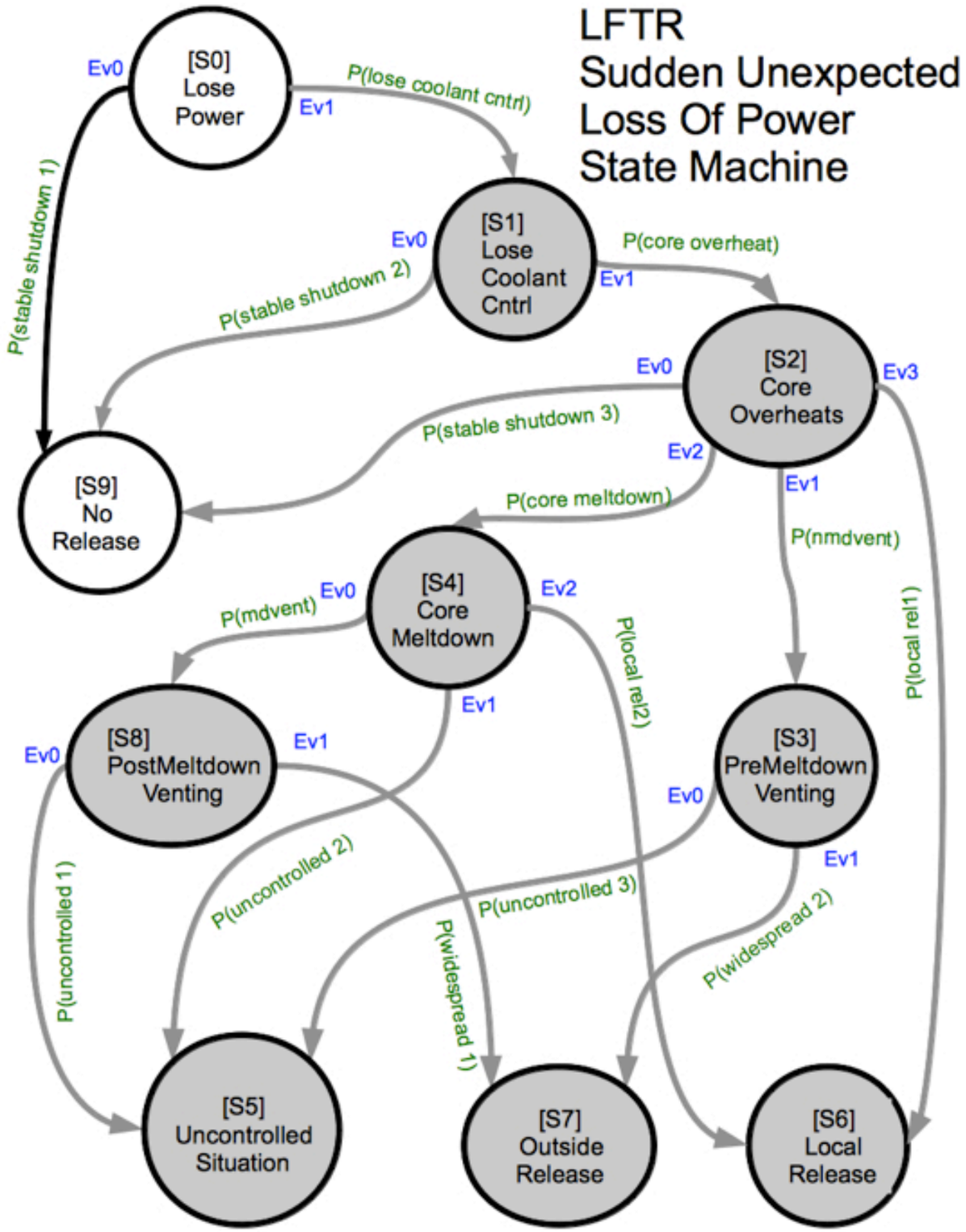
# Updated Simulations and Results

# State Machine for Sudden Unexpected Loss Of Power [Conventional Solid Fuel High Pressure Light Water Reactor]



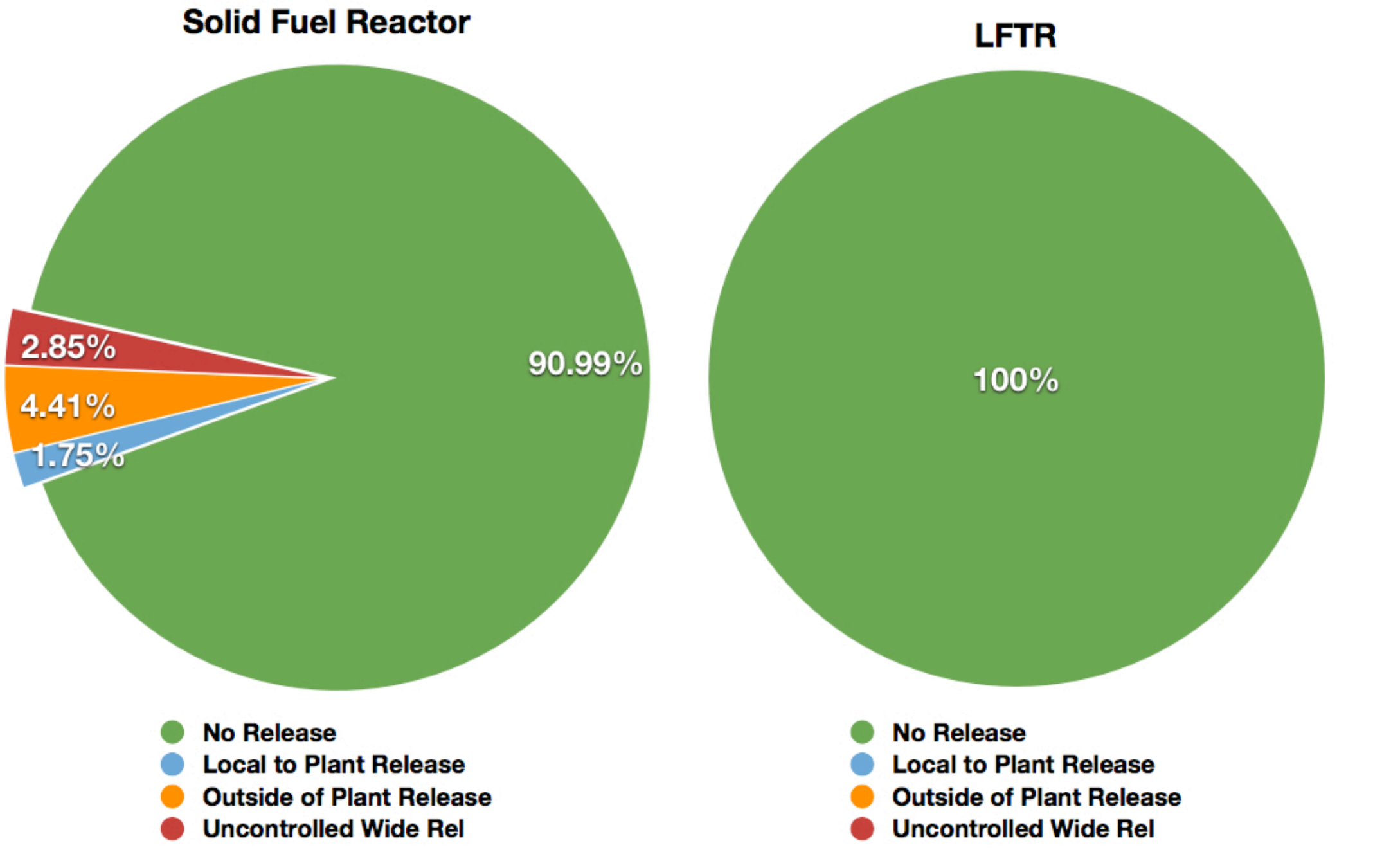

| Transition Probabilities for Sudden Unexpected Loss Of Power Event | |
|---|---|
| **Probability Symbol** | **Solid Fuel Reactor** |
| Stable Shutdown 1 | 80% |
| Lose Coolant Cntrl | 20% |
| Stable Shutdown 2 | 50% |
| Core Overheat | 50% |
| Stable Shutdown 3 | 10% |
| Core Meltdown | 25% |
| Pre-Meltdown Venting | 50% |
| Local Release 1 | 15% |
| Post Meltdown Venting | 70% |
| Uncontrolled Sit 2 | 20% |
| Local Release 2 | 10% |
| Uncontrolled Sit 1 | 20% |
| Widespread Release 1 | 80% |
| Uncontrolled Sit 3 | 40% |
| Widespread Release 2 | 60% |

# State Machine for Sudden Unexpected Loss Of Power [LFTR]

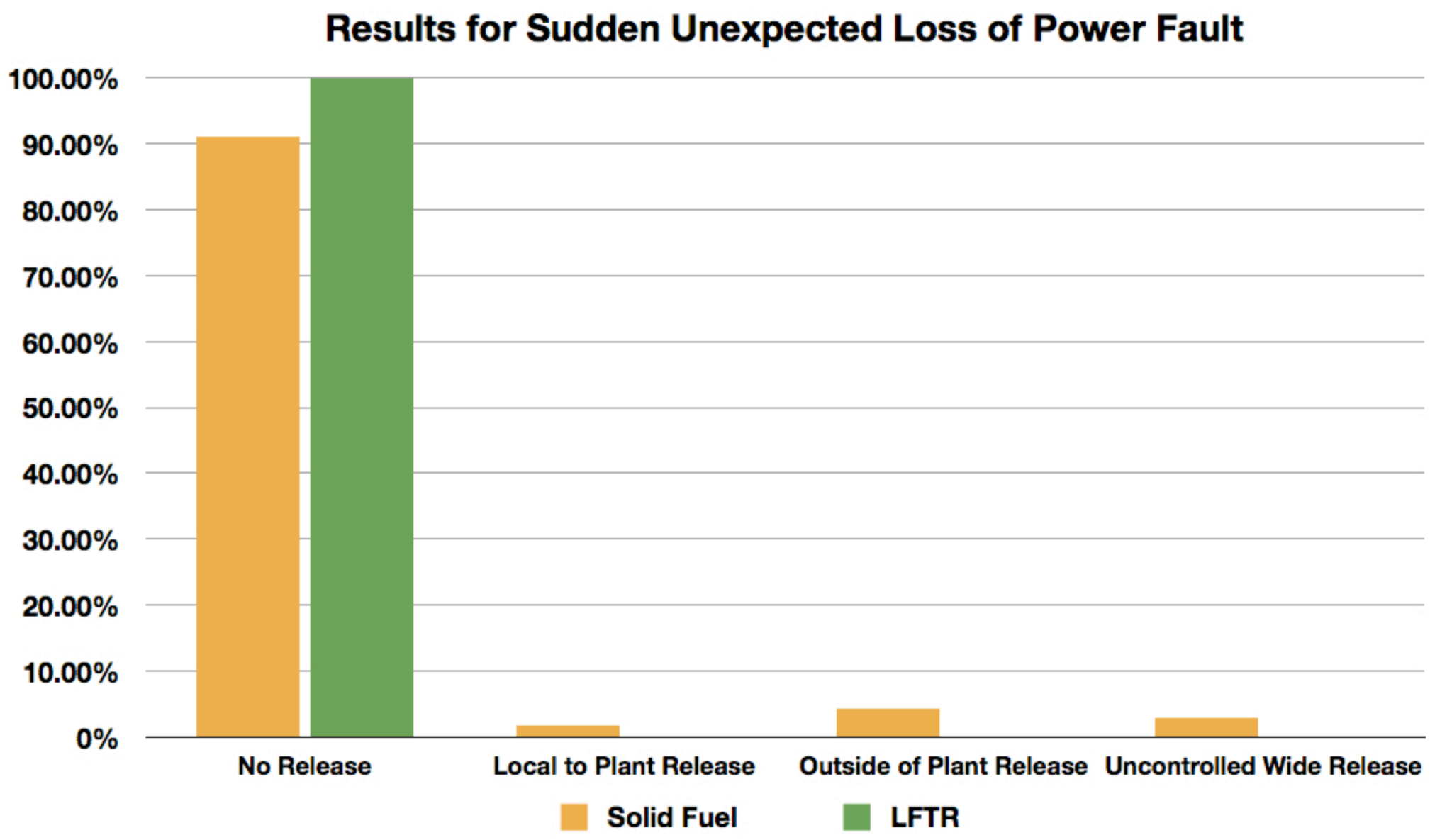



| Transition Probabilities for Sudden Unexpected Loss Of Power Event | |
|---|---|
| **Probability Symbol** | **LFTR** |
| Stable Shutdown 1 | 100% |
| Lose Coolant Cntrl | 0% |
| Stable Shutdown 2 | 0% |
| Core Overheat | 0% |
| Stable Shutdown 3 | 0% |
| Core Meltdown | 0% |
| Pre-Meltdown Venting | 0% |
| Local Release 1 | 0% |
| Post Meltdown Venting | 0% |
| Uncontrolled Sit 2 | 0% |
| Local Release 2 | 0% |
| Uncontrolled Sit 1 | 0% |
| Widespread Release 1 | 0% |
| Uncontrolled Sit 3 | 0% |
| Widespread Release 2 | 0% |

# Results for Sudden Unexpected Loss Of Power Fault Condition

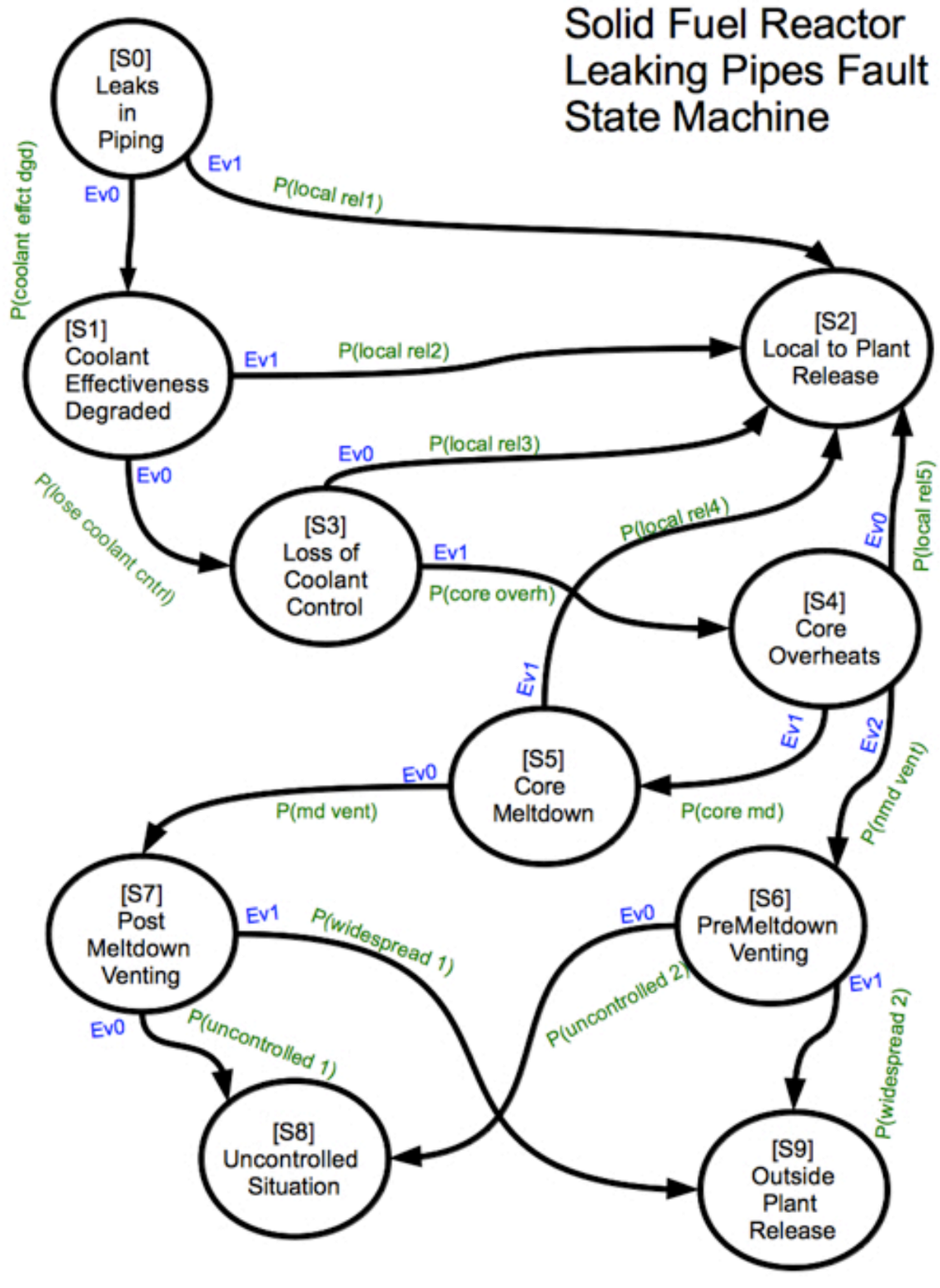


# Results for Sudden Unexpected Loss Of Power Fault Condition



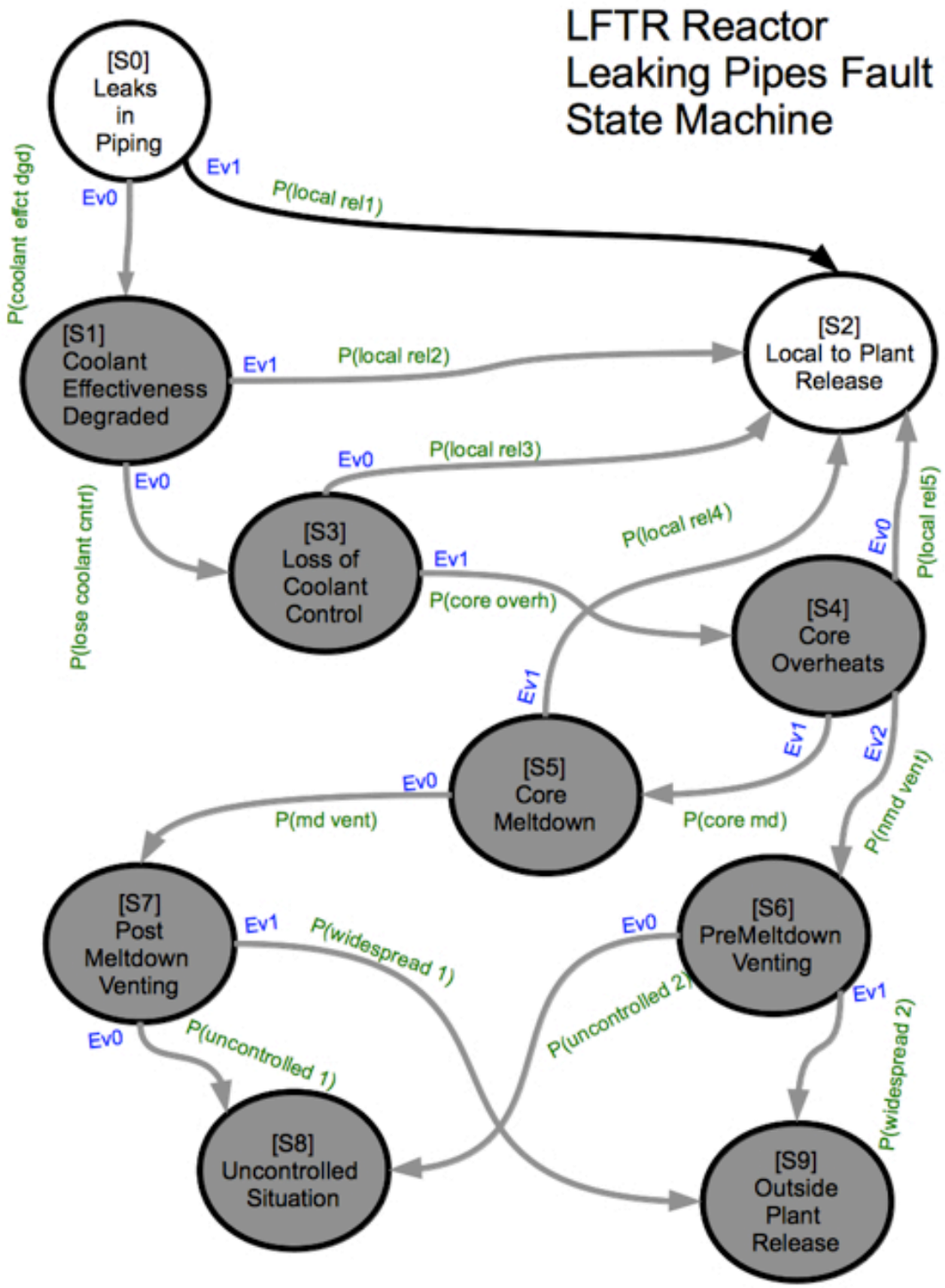

| | No Release | Local to Plant Release | Outside of Plant Release | Uncontrolled Wide Release |
|---|---|---|---|---|
| Solid Fuel | 90.99% | 1.75% | 4.41% | 2.85% |
| LFTR | 100.00% | 0.00% | 0.00% | 0.00% |

# State Machine for Leaks in Piping
# [Conventional Solid Fuel High Pressure Light Water Reactor]



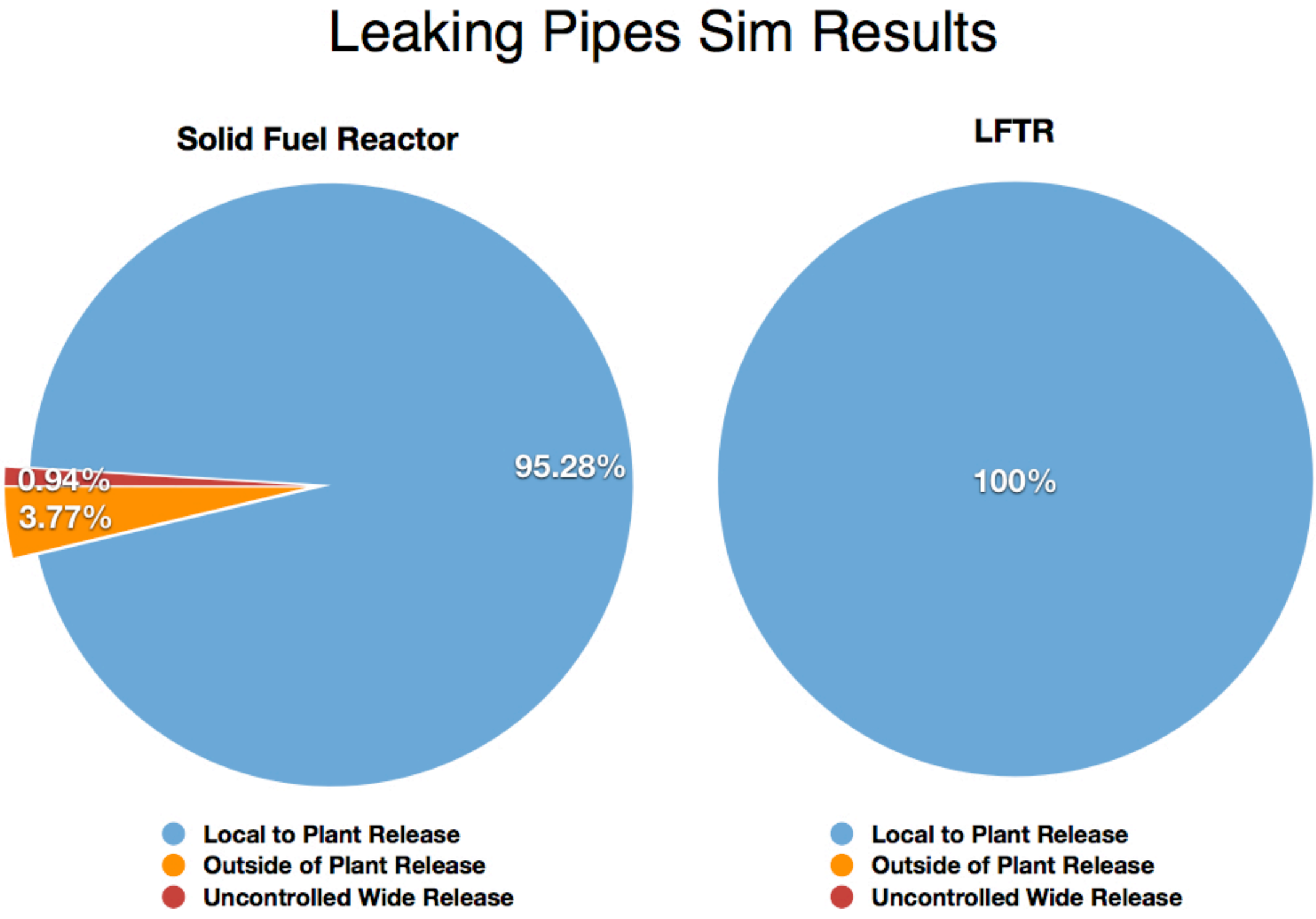

| Transition Probabilities for Leaky Pipes Event | |
|---|---|
| **Probability Symbol** | **Solid Fuel Reactor** |
| Local Release 1 | 75.00% |
| Coolant Effect Degraded | 25.00% |
| Local Release 2 | 80.00% |
| Local Release 3 | 60.00% |
| Lose Coolant Control | 20.00% |
| Core Overheat | 40.00% |
| Local Release 4 | 30.00% |
| Local Release 5 | 20.00% |
| Core Meltdown | 30.00% |
| Non-Meltdown Venting | 50.00% |
| Meltdown Venting | 70.00% |
| Widespread Release 1 | 80.00% |
| Widespread Release 2 | 80.00% |
| Uncontrolled Sit 1 | 20.00% |
| Uncontrolled Sit 2 | 20.00% |

# State Machine for Leaks in Piping [LFTR]

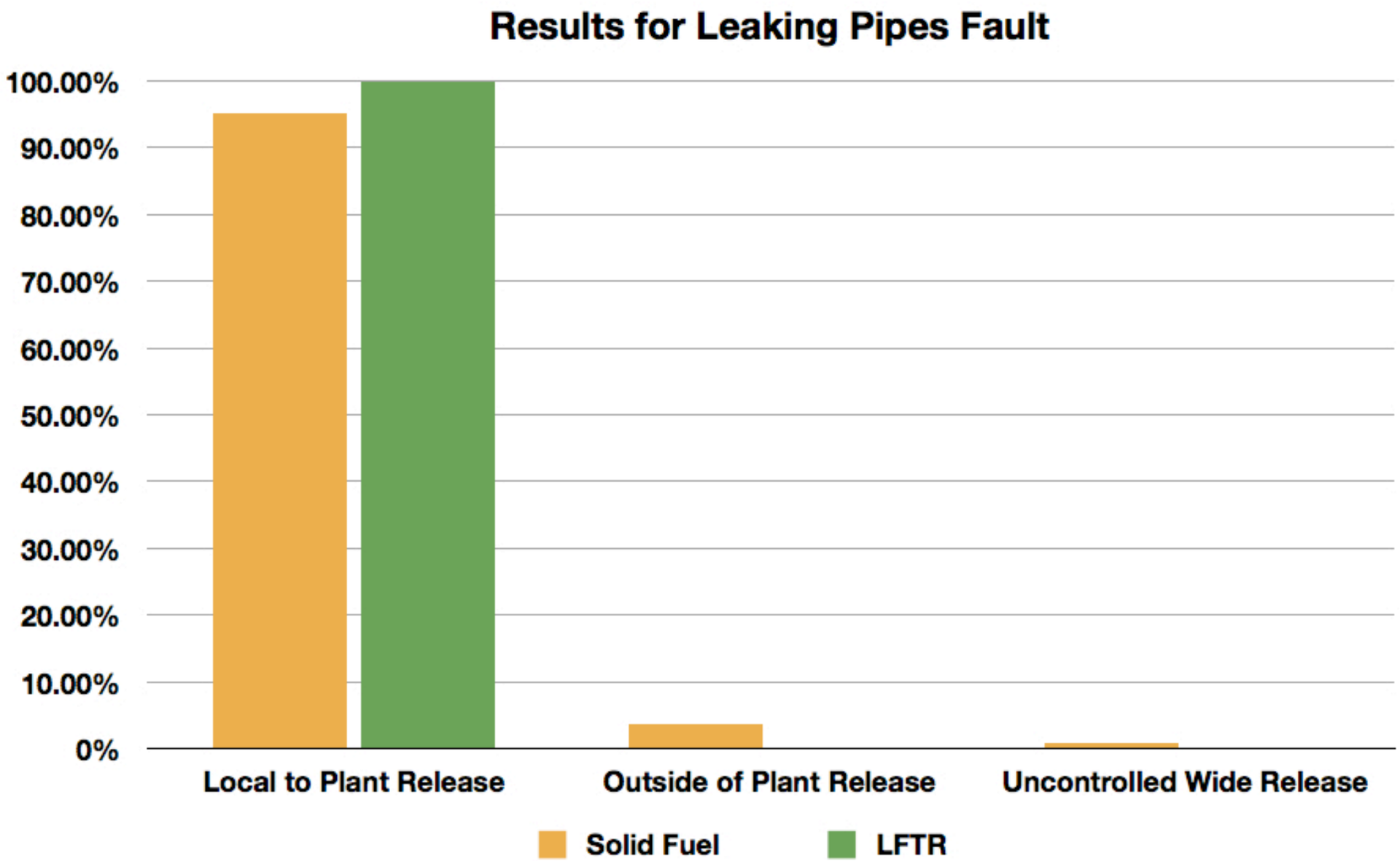



| Transition Probabilities for Leaky Pipes Event | |
|---|---|
| **Probability Symbol** | **LFTR** |
| Local Release 1 | 100.00% |
| Coolant Effect Degraded | 0.00% |
| Local Release 2 | 0.00% |
| Local Release 3 | 0.00% |
| Lose Coolant Control | 0.00% |
| Core Overheat | 0.00% |
| Local Release 4 | 0.00% |
| Local Release 5 | 0.00% |
| Core Meltdown | 0.00% |
| Non-Meltdown Venting | 0.00% |
| Meltdown Venting | 0.00% |
| Widespread Release 1 | 0.00% |
| Widespread Release 2 | 0.00% |
| Uncontrolled Sit 1 | 0.00% |
| Uncontrolled Sit 2 | 0.00% |

# Results for Leaks in Piping Fault Condition



# Results for Leaks in Piping Fault Condition




| | Local to Plant Release | Outside of Plant Release | Uncontrolled Wide Release |
|---|---|---|---|
| **Solid Fuel** | **95.28%** | **3.77%** | **0.94%** |
| **LFTR** | **100.00%** | **0.00%** | **0.00%** |

# Sample “Element Comic”

# Hide-and-Seek with Helium and Sodium


*Note: the original comic, drawn when I was nine, was harder to read. This is a more legible redrawing of that comic.*

# Play Synopses

# It’s Elementary!

It's Elementary!

by Katie Hudek

Copyright © 2011, 2012 by Katherine Hudek

## Synopsis

A comedy-adventure involving chemistry, puppies, kittens, and danger.

Normally, elements from one group will combine with others from different groups to form new compounds with a stable outer shell. This story is about immature elements portrayed as dogs and cats, who live on mythical Element Island and initially only want to associate with elements within their same group on the periodic table. When a danger threatens their island they have to face it, and in the process learn that they're stronger when they combine and act together.

## Principal Characters

**ALUMINUM**: White Oriental kitten, gentle and easygoing, but perseverant if she finds trouble.

**CURIUM**: Seal Point Birman kitten,a social butterfly; has a fiery temper

**BORON**: Fawn Great Dane puppy, is quite fun to be with in spite of his name

**ARGON**: an arrogant black and white Saluki puppy, doesn’t mix well with others; a troublemaker

**CARBON**: Orange kitten; doesn’t get along with Boron

**GOLD**: Golden Retriever puppy; female; played by a younger actress; brave and determined; likes to retrieve things and is always hungry

**SILVER**: Irish Wolfhound puppy; male; played by a younger actor; timid and a little submissive

**PLATINUM**: Parson Russell Terrier puppy; male; played by a younger actor; fiery and spunky

**GRENDALIAN**: Over-the-top comedic monster

# The Great Electron Mystery!

## The Great Electron Mystery!

by Katie Hudek

Copyright © 2012 by Katherine Hudek

## Synopsis

A comedy-mystery involving chemistry, puppies, kittens, and mice.

A sequel to "It's Elementary" set on the same Element Island. The elements have learned to combine to form compounds, but a mystery arises when electrons go missing. Neutrinos are introduced, who help the elements solve the mystery and one element learns about friendship.

## Principal Characters

**NEUTRINA**: female gray baby mouse, a neutrino, is the opposite of her brother in some ways; searching for the Higgs Boson

**TEOFIL**: male gray baby mouse, a neutrino, Neutrina's sister; searching for the Higgs Boson

**GOLD**: female Golden Retriever puppy

**HYDROGEN**: female white Westie puppy, has a great number of friends and elements that she combines with.

**OXYGEN**: male tricolored Hamiltonstovare hound puppy; smart and a bit shy

**LEAD**: male brown Bloodhound puppy; nice, but a bit dense; easily tricked

**LITHIUM**: female sable ticked Singapura kitten; soft-spoken, gentle, and very pretty; likes Radon

**RADON**: male brown Sphynx kitten (Note: Sphynx cats are hairless); seems bad but is actually misled and has good heart; likes Lithium