



The Role of Geothermal in Enhancing Energy Diversity and Security in the Western US

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A Mean-Variance Portfolio Optimization of the Region's Generating Mix to 2013

Prepared for Sandia National Labs

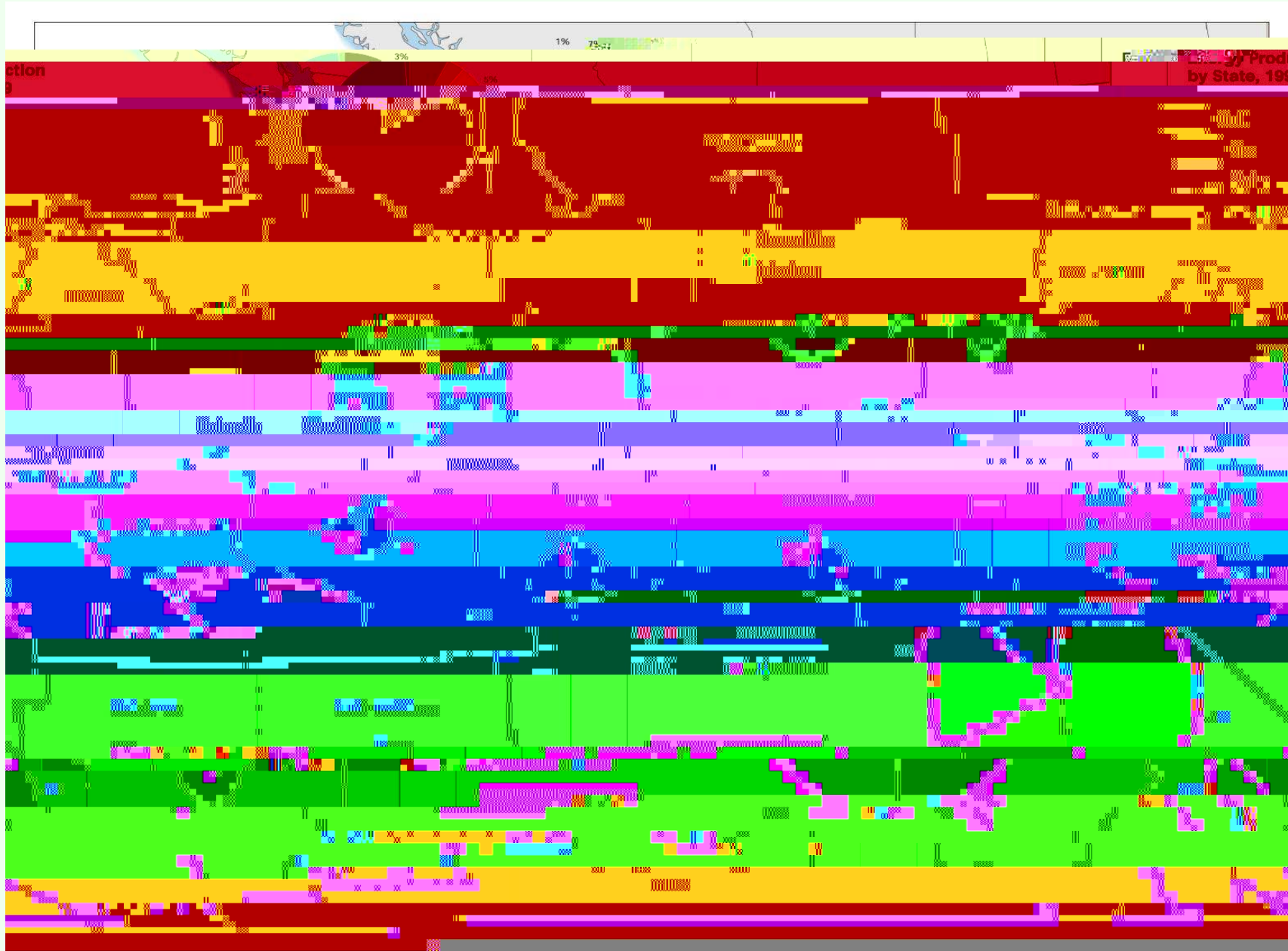
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Contract Officer**

By

Shimon Awerbuch, Ph.D.

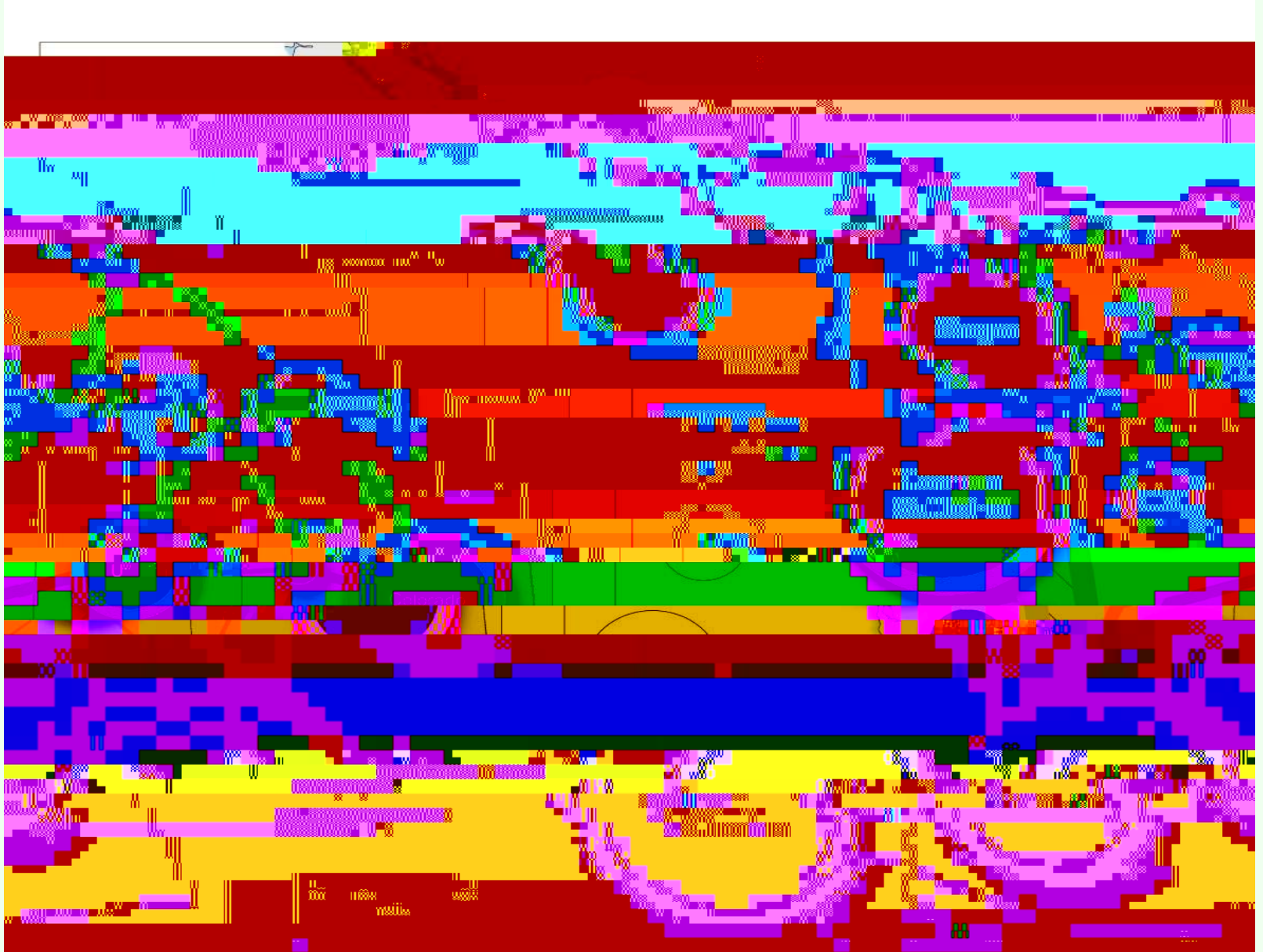
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Electricity Generation



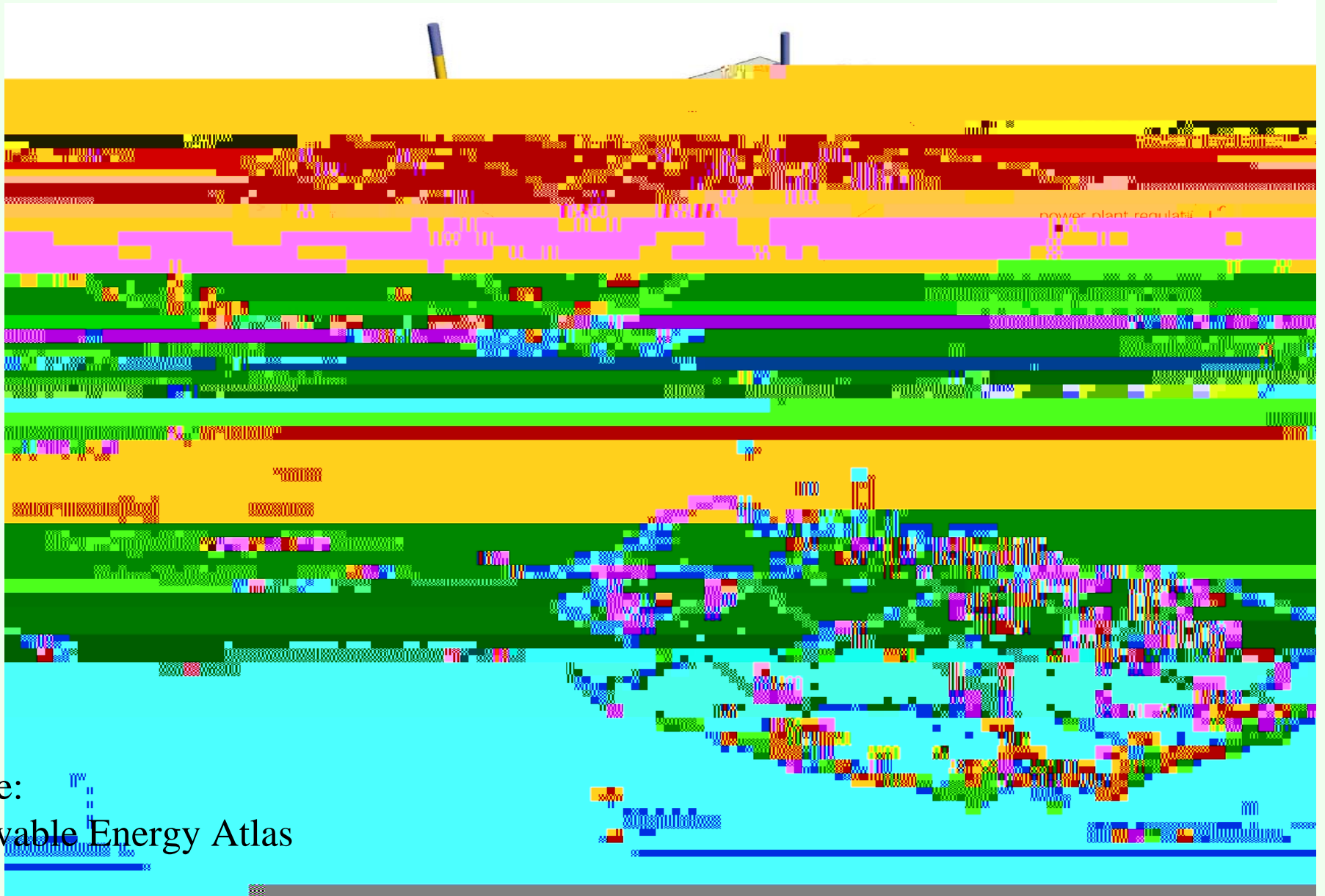
Source:
Renewable
Energy Atlas

Western US: Load Growth



Source:
Renewable
Energy Atlas

Regional Power Plant Emissions

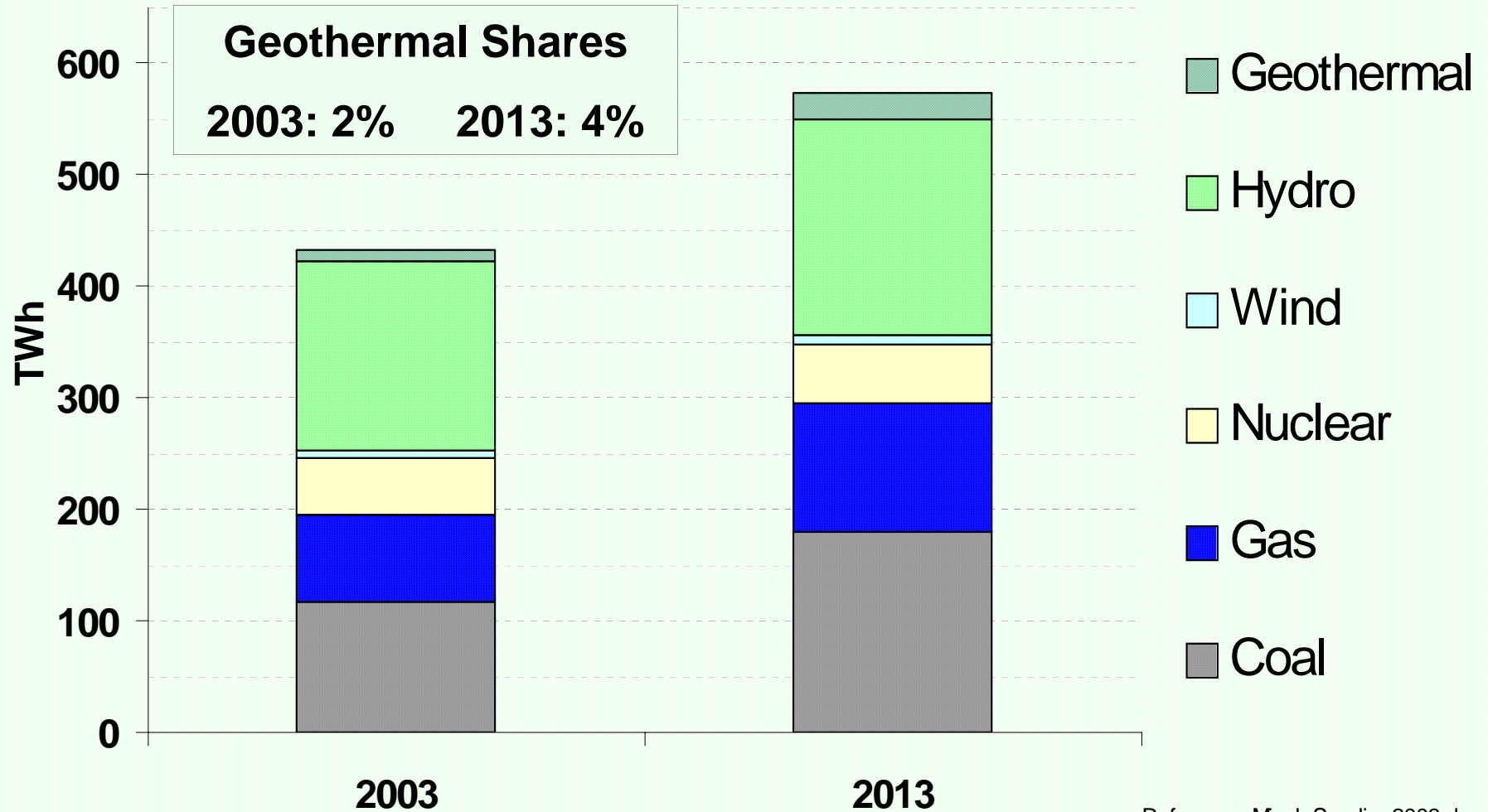


Source:
Renewable Energy Atlas

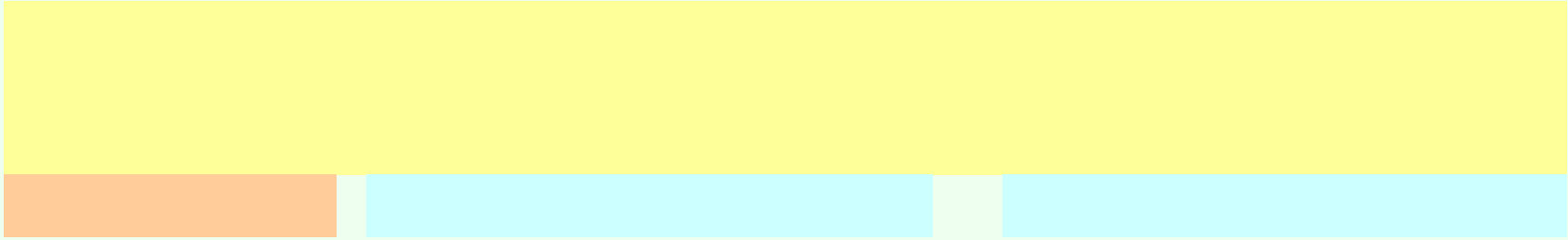
**Optimization Defines Four Bands for
New Geothermal Based es Tc -0inB 55Bi for**



EIA 2003 and 2013 Generating Mixes



Generating Cost Inputs: Nominal \$/kWh



Understanding Risk

- **Portfolio optimization locates generating mixes with minimum expected cost and risk**
- **For each technology, risk is the year-to-year variability (standard deviation) of the three generating cost inputs: fuel, O&M and capital (construction period risk)**
 - Fossil fuel standard deviations are estimated from historic US data
 - e.g. standard deviation for natural gas over the last 10 years is 0.30
 - Standard deviations for capital and O&M are estimated using proxy procedures (see Awerbuch and Berger, IEA, 2003)
- **The construction period risk for embedded technologies is 0.0**
- **'New' technologies are therefore riskier than embedded ones**
 - e.g. new coal is riskier than 'old' coal

A Mean-Variance Portfolio Optimization of the Western Region's Generating Mix to 2013

- **Portfolio optimization locates generating mixes with lowest-expected cost at every level of risk**
 - Risk is the year-to-year variability of technology generating costs
- EIA (NEMS) projected generating mixes serve as a benchmark or starting point;
 - Detailed decommissioning date assumptions using *World Electricity Power Plant Database* age of existing plants
- The optimal results generally indicate that compared to EIA target mixes, there exist generating mixes with larger geothermal shares at no greater expected cost or risk
 - There exist mixes with larger geothermal shares that exhibit *lower* expected cost and risk

