Modelling of Resilient Electricity Generation after Cascading Collapse

New England Case Study

Presentation of the
Foundation for Resilient Societies

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All data and conclusions are preliminary pending review with ISO-New England

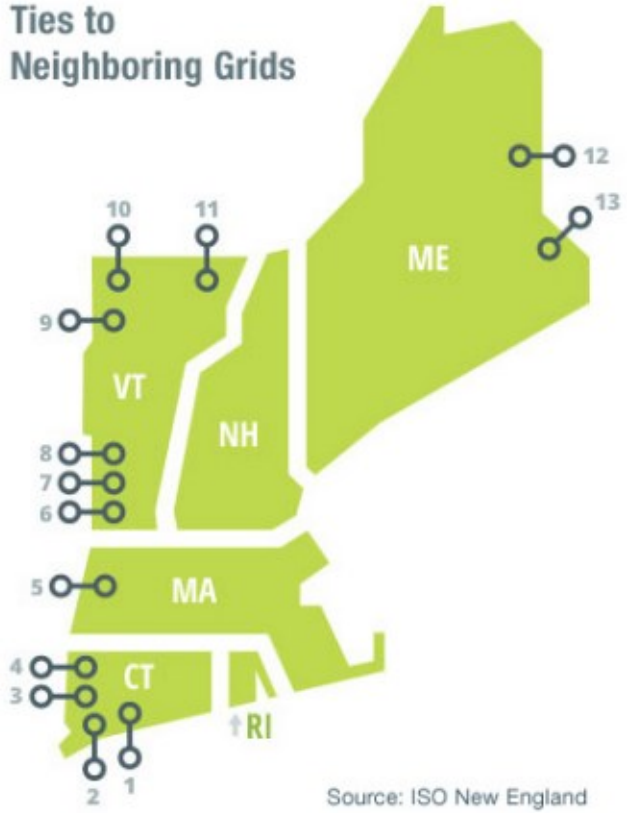
Executive Summary

- **New England has minimal energy production and storage; region is dependent on imports**
- **We modelled cyber/physical attack scenario**
  - **Loss of gas compressor stations and SCADA control**
  - **Cascading collapse of Northeast electric grid**
- **Key findings:**
  - **With careful use of gas line pack, coal and petroleum stored on-site, and dual fuel plants, rolling blackouts can be largely avoided for several weeks**
  - **But without coal and nuclear plants, model projects persistent blackouts**
  - **Retirements of oil-fired plants also risk blackouts**

New England Grid as Case Study in Limited Energy Storage

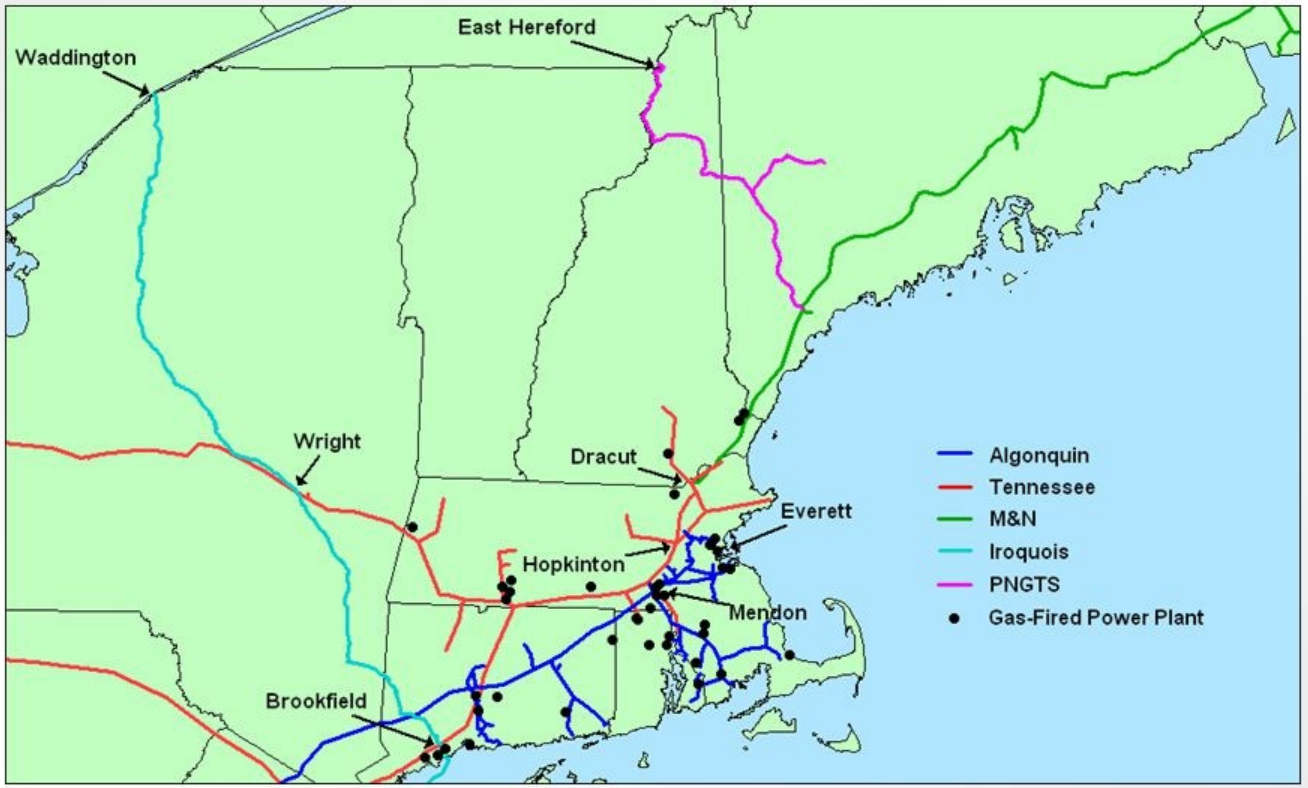
Electricity Flows into New England

- **New York: 1-9**
  - **AC ties**
- **Hydro-Quebec: 10-11**
  - **Highgate HVDC**
  - **Phase II HVDC**
- **New Brunswick: 12-13**
  - **AC ties**



Interstate Pipelines Serving New England

Total Deliverability over 4.0 Bcf/d



Source: "Outlook on Natural Gas and LNG in New England," New England Roundtable, November 2004.

Modelling of Resilient Electricity Generation and Demand

Cascading Collapse Scenario

Commencing on January 1st

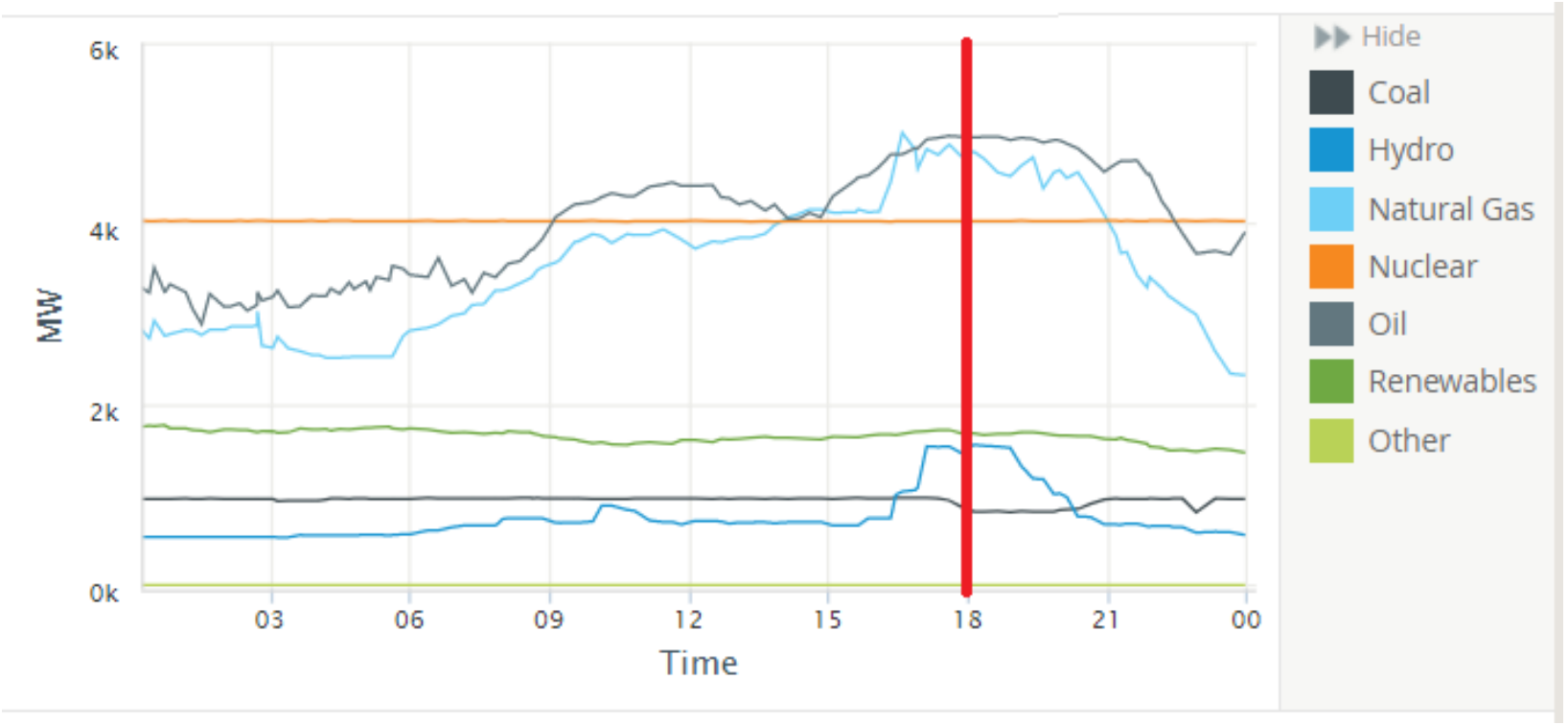
- **Combined cyber/physical attack at 6pm load peak**
  - **Loss of compressors for Northeast natural gas pipelines**
  - **Cascading collapse of ISO-New England grid**
- **All energy import into New England stops**
- **All nuclear power plants trip and SCRAM**
- **Resupply of oil-fired plants is difficult or impossible**
- **New England must rely almost entirely on its own stored energy sources for two weeks**
  - **Hydro-Quebec HVDC imports resume after restart**

Methodology

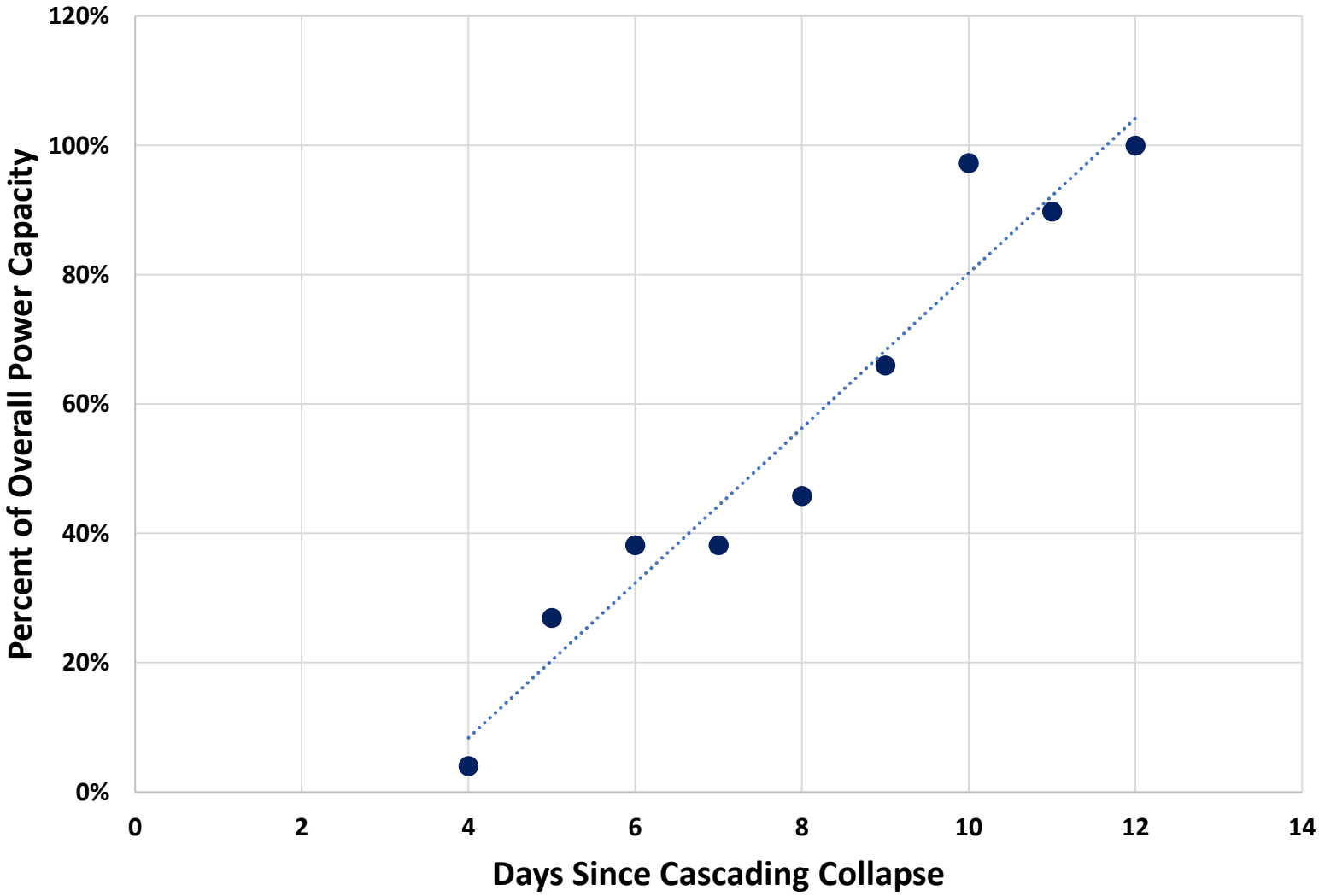
- **Use ISO-NE load profile from January 1-15, 2018**
- **Renewable generation from same time period**
  - **Wind, solar, landfill gas, wood, municipal waste, etc.**
- **Develop baseline profiles of resources over time**
  - **Natural gas, oil-fired, coal, nuclear, hydro, imports, DR**
- **Heat rates and BTU content of fuel from EIA for fossil fuel generators**
- **Matched EIA Form 860 for fossil fuel ramp rates**
- **Modelled start time and ramp for nuclear plants**
- **Model electricity generated at unit level**
- **Model fuel consumed at plant level**

ISO-New England Generation Fuel Mix

Scenario Start at 18:00 Hours on January 1st



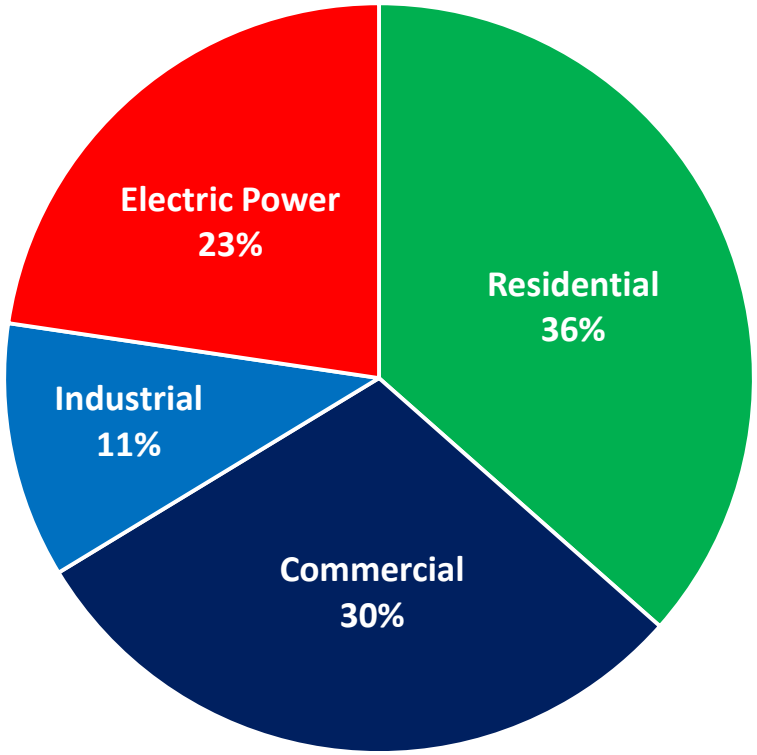
August 14, 2003 Nuclear Plant Trips



Key Assumptions

- **Gas pipeline line pack is near daily maximum**
  - **34% of line pack available for electricity generation**
- **All oil tanks at generation plants are full**
- **Dual-fuel plants run exclusively on oil**
- **Mystic Generating Station is fully operational**
- **Distrigas LNG tanks full; 80% of re-gas for Mystic**
- **River flow for hydroelectric plants near maximum**
- **No electricity imports except HVDC hydropower**
- **No transmission constraints**
- **Nuclear plants receive NRC approval to operate**

New England Natural Gas Consumption
January 2018



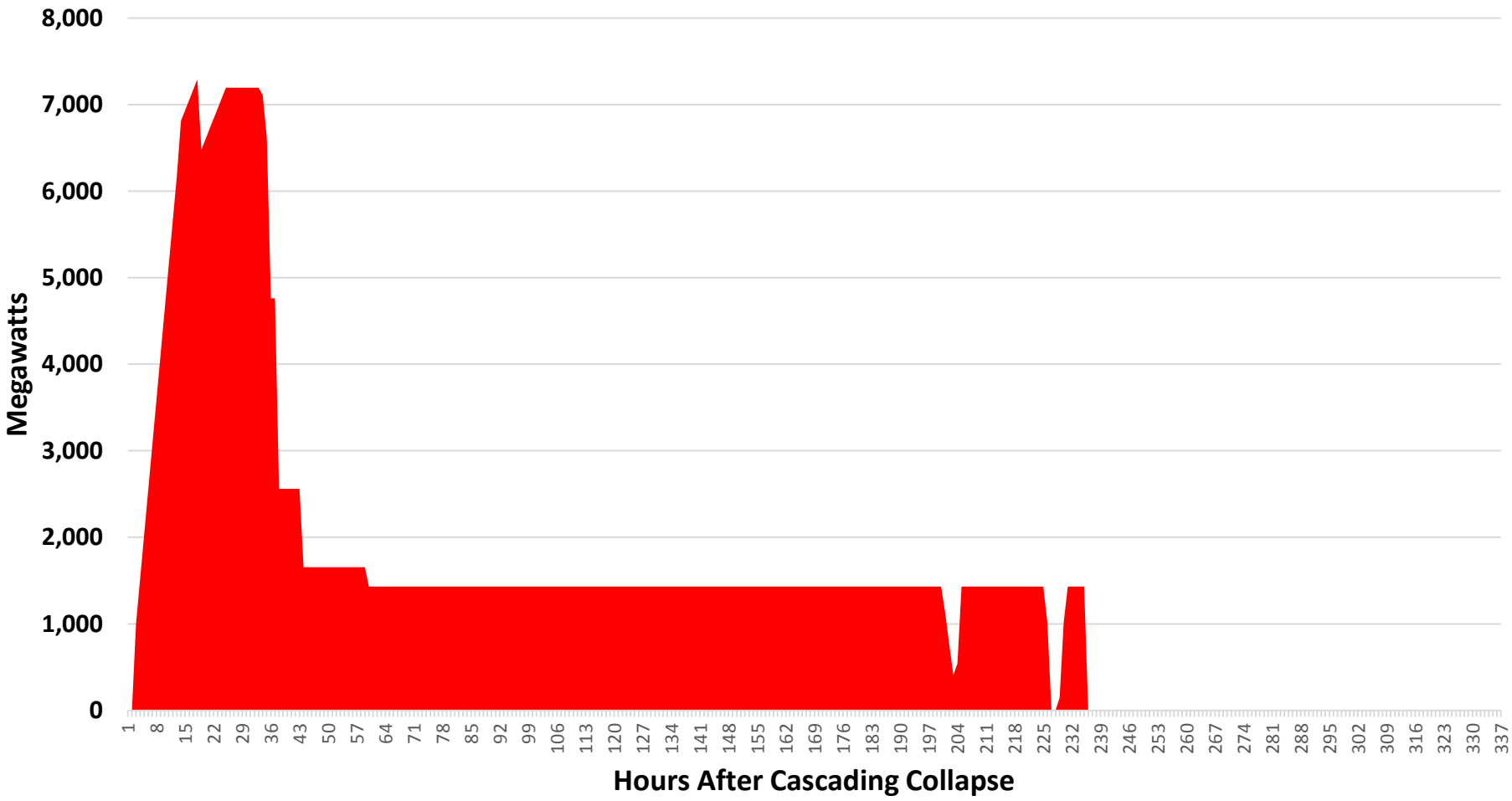
Source: EIA Natural Gas Consumption by End Use

Estimation of Fuel Tank Capacities

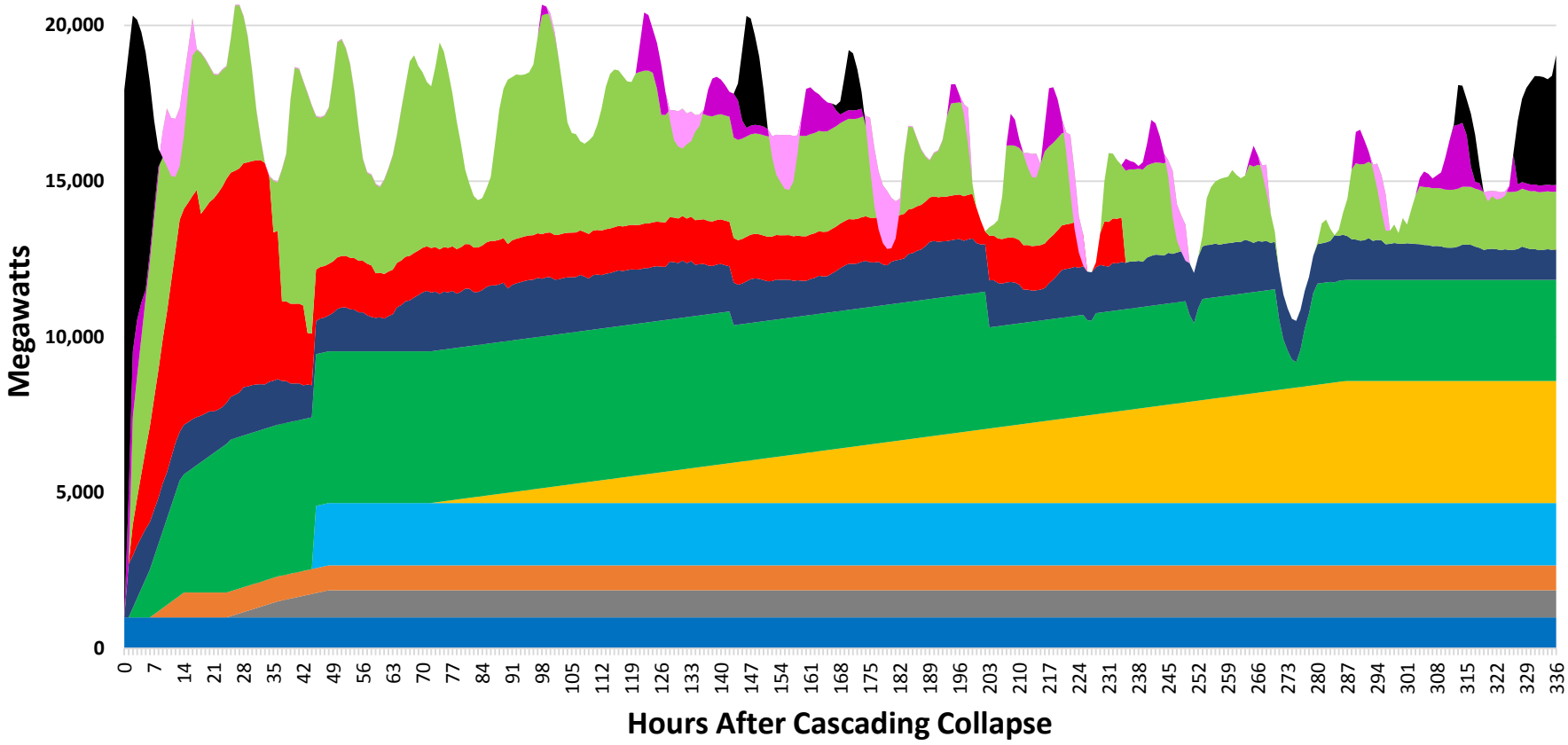
Source: Google Earth, Resilient Societies analysis

New England Energy Scenarios

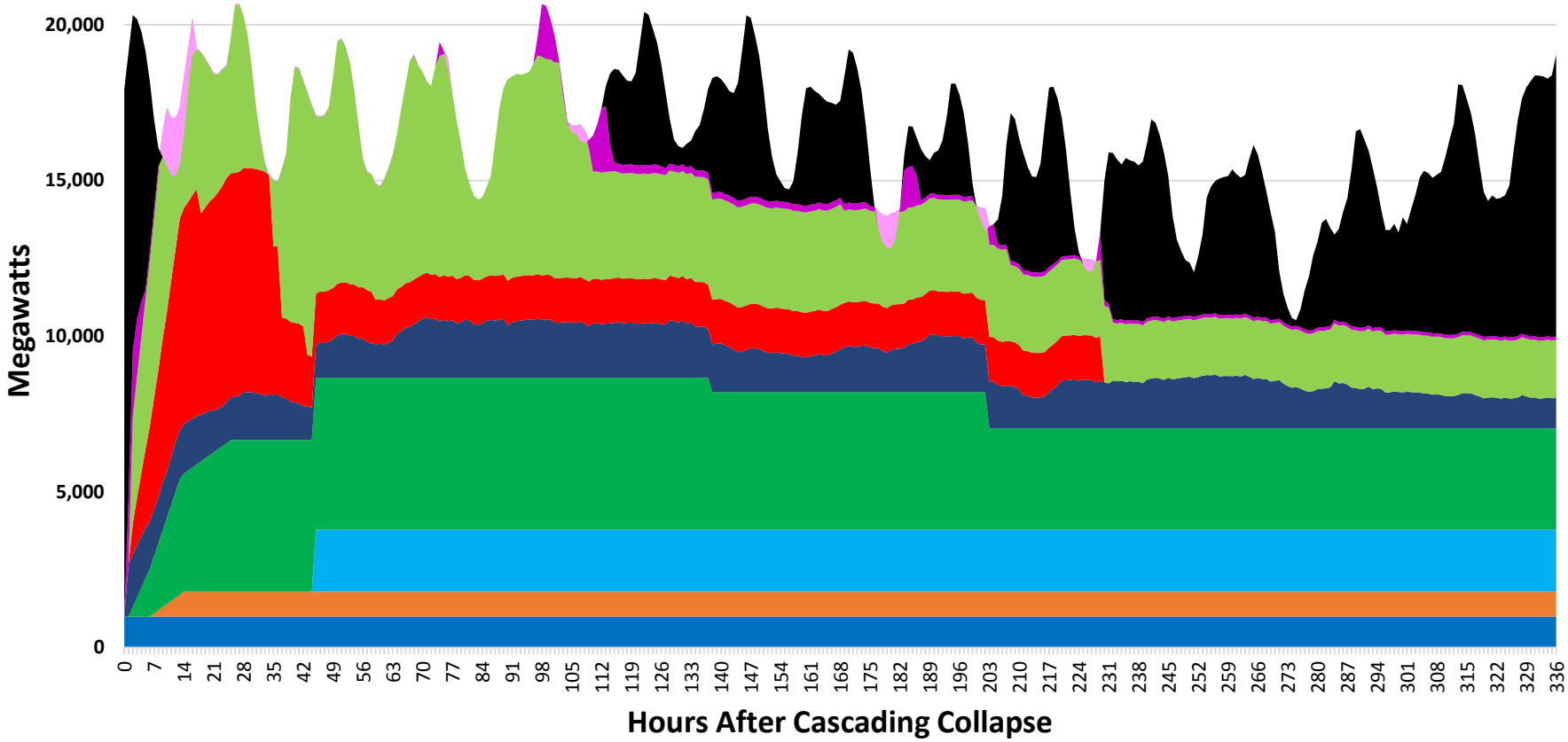
Gas-Fired Generation Profile



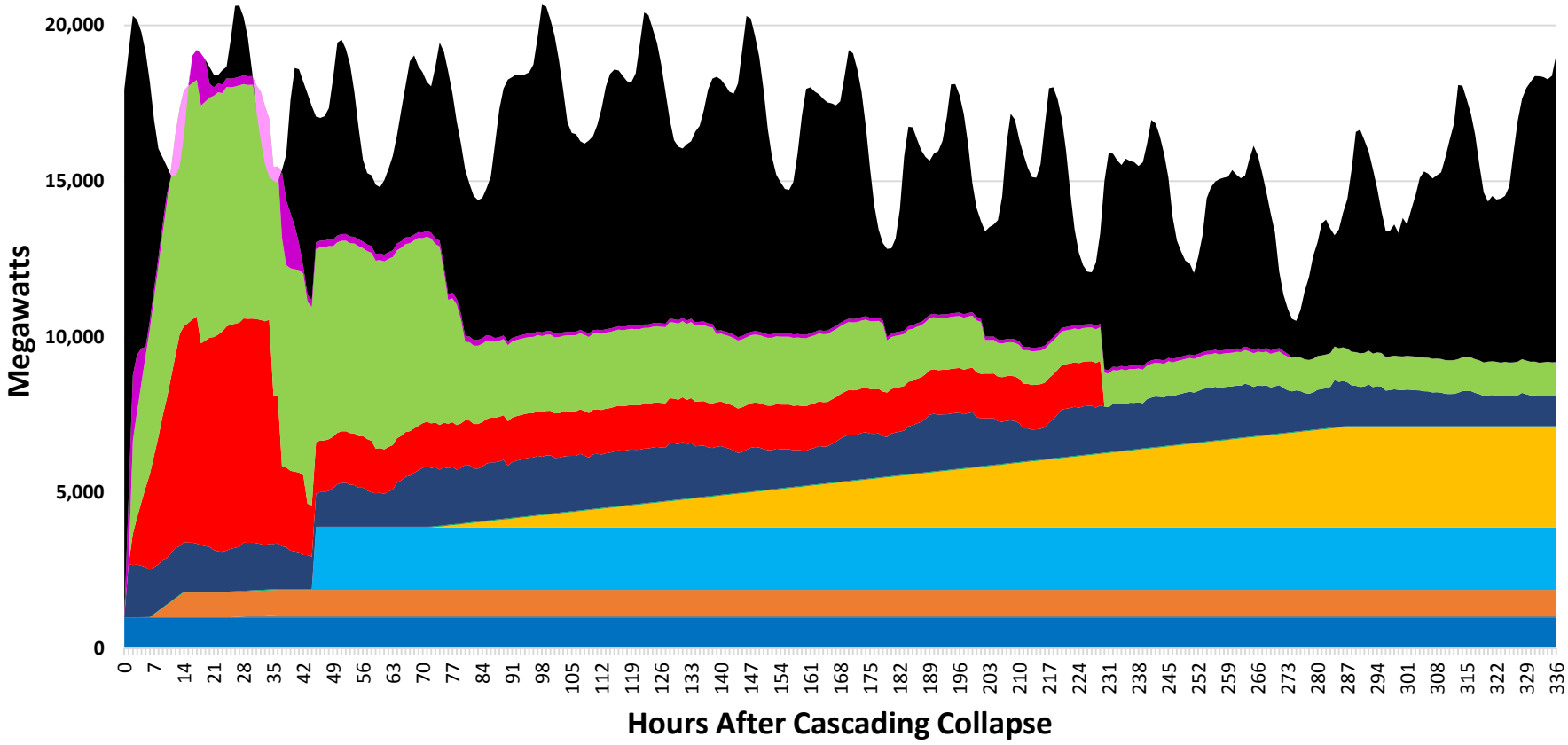
New England Energy Scenario After Cyber/Physical Attack During January with 2018 Generation Fleet



New England Energy Scenario After Cyber/Physical Attack During January with All Coal and Nuclear Plants Retired



New England Energy Scenario After Cyber/Physical Attack During January with ISO-NE "At Risk" Plants Retired



Summary Conclusions

- **With current generation fleet, rolling blackouts after cyber/physical attack could be limited and manageable**
- **If generation capacity with fuel stored on-site retires, load sheds could be one-third to one-half of peak demand**
  - **Repeated challenges with cold-load pickup over many days**
  - **Too large a shortfall for effective demand response**
- **More generation capacity with zero or limited on-site energy storage will not protect against rolling blackouts**
  - **Natural gas generators dependent on non-firm contracts**
  - **Dual-fuel plants with only a few days of energy storage**
  - **Renewables inherently limited by wind and daylight hours**
- **Risk of major societal disruptions without on-site energy**
  - **Hard to discriminate between critical and non-critical loads**
  - **Blackouts for hospitals, fire stations, police, jails, pharmacies, etc.**

For More Information

- ***To get a copy of our presentation, please send an email to: info@resilientsocieties.org***
- **Foundation for Resilient Societies is an IRS-approved 501(c)(3) charitable organization with the mission of critical infrastructure protection. Learn more by visiting www.resilientsocieties.org**
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