Impact of intermittent renewable energy sources (RES) on electricity production in Italy

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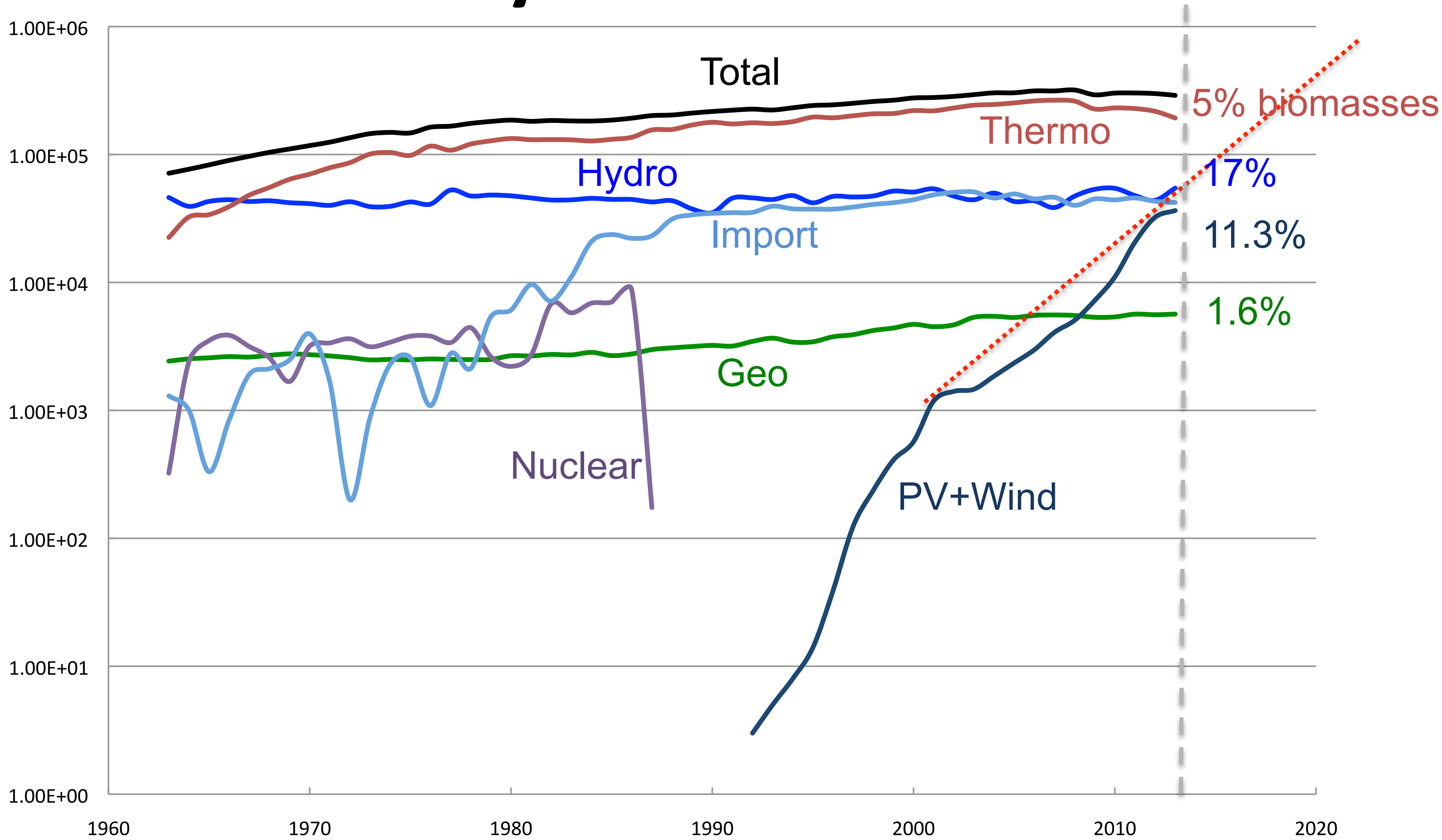
Italy already achieved the 2020 objective of 35% electricity from renewable sources



Source: TERNA Dati Statistici 2013

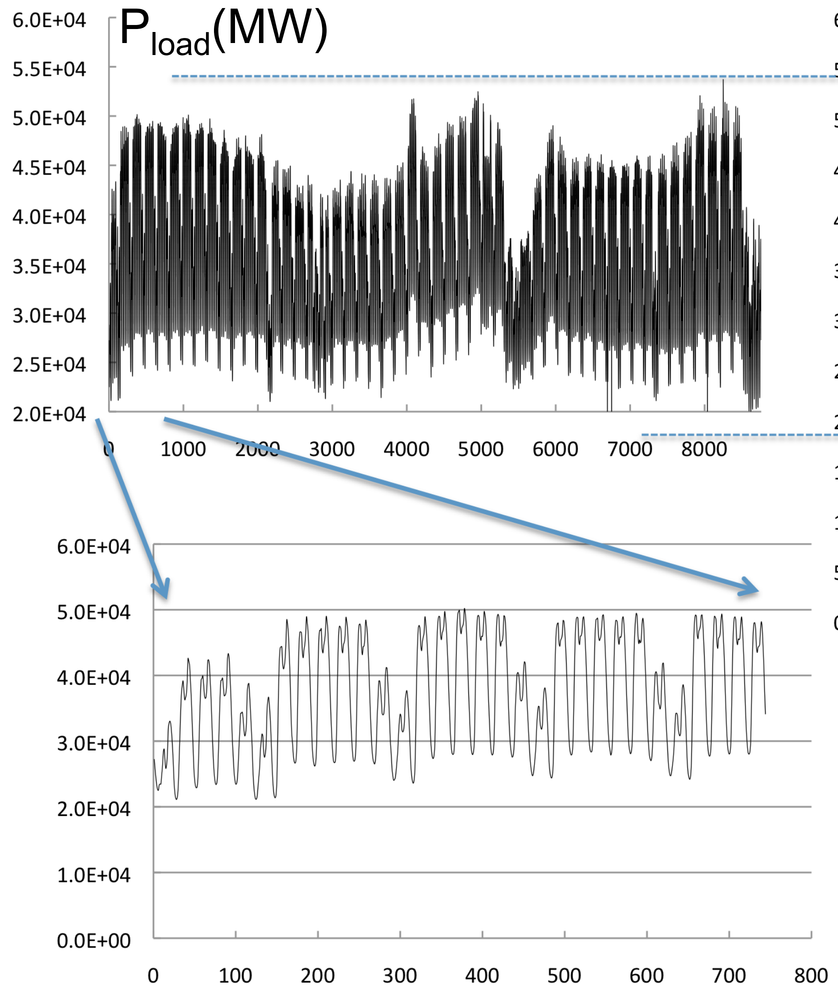
Motivation

- **Case study: electric energy produced by RES equal to the annual electricity demand.**
- However, for the periods with insufficient RES production **back-up systems** (thermal plants) have to be kept in operation.
- How large the installed **back-up power** must be?
- Requirements for the storage to avoid/reduce the back-up power?
- Impact on the power managed by the grid?

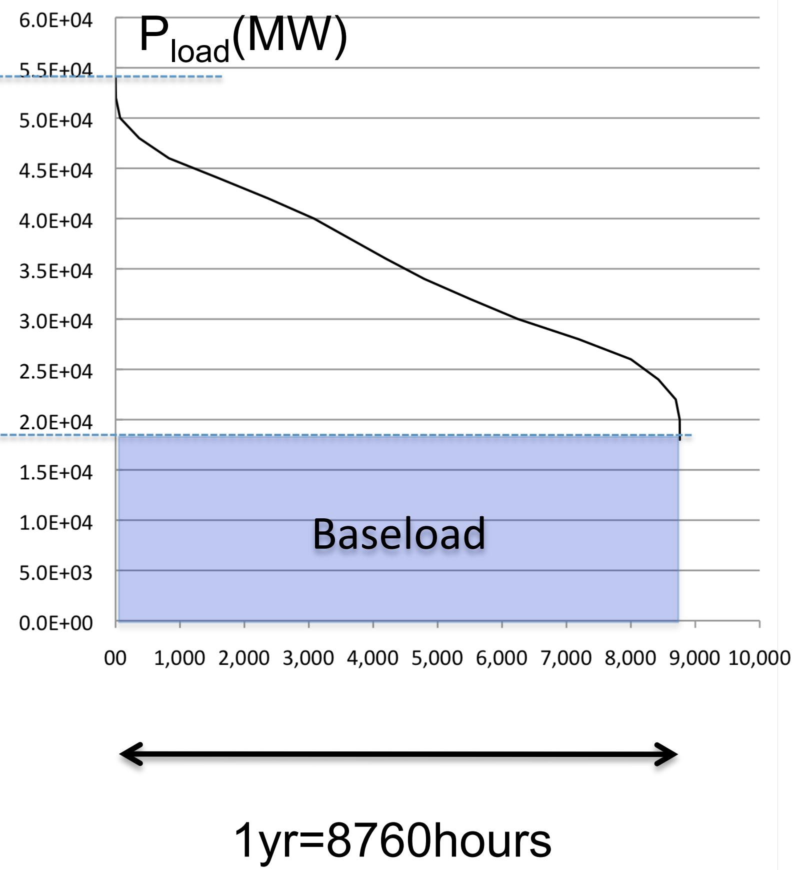
Data analysis

- Data for the year 2013 (load and renewables generation) from the grid operator TERNA. Data averaged over 1 hour.
- Demand (load) kept at the 2013 value.
- PV and wind generation **scaled-up** in order to mach annual electricity demand.
- Hydroelectric and geothermal generation at 2013 values
- With this input evaluate for each 1h time interval:
  - the back-up power $\mathbf{P_{backup} \equiv P_{load} - P_{PV} - P_{Wind}}$
  - the back-up energy $\equiv \int_{year} dt\, P_{back\text{-}up}$
  - If $\mathbf{P_{backup}}<0$ define $\mathbf{P_{surplus}} = -\mathbf{P_{backup}}$
- Free parameters: storage capacity and PV share

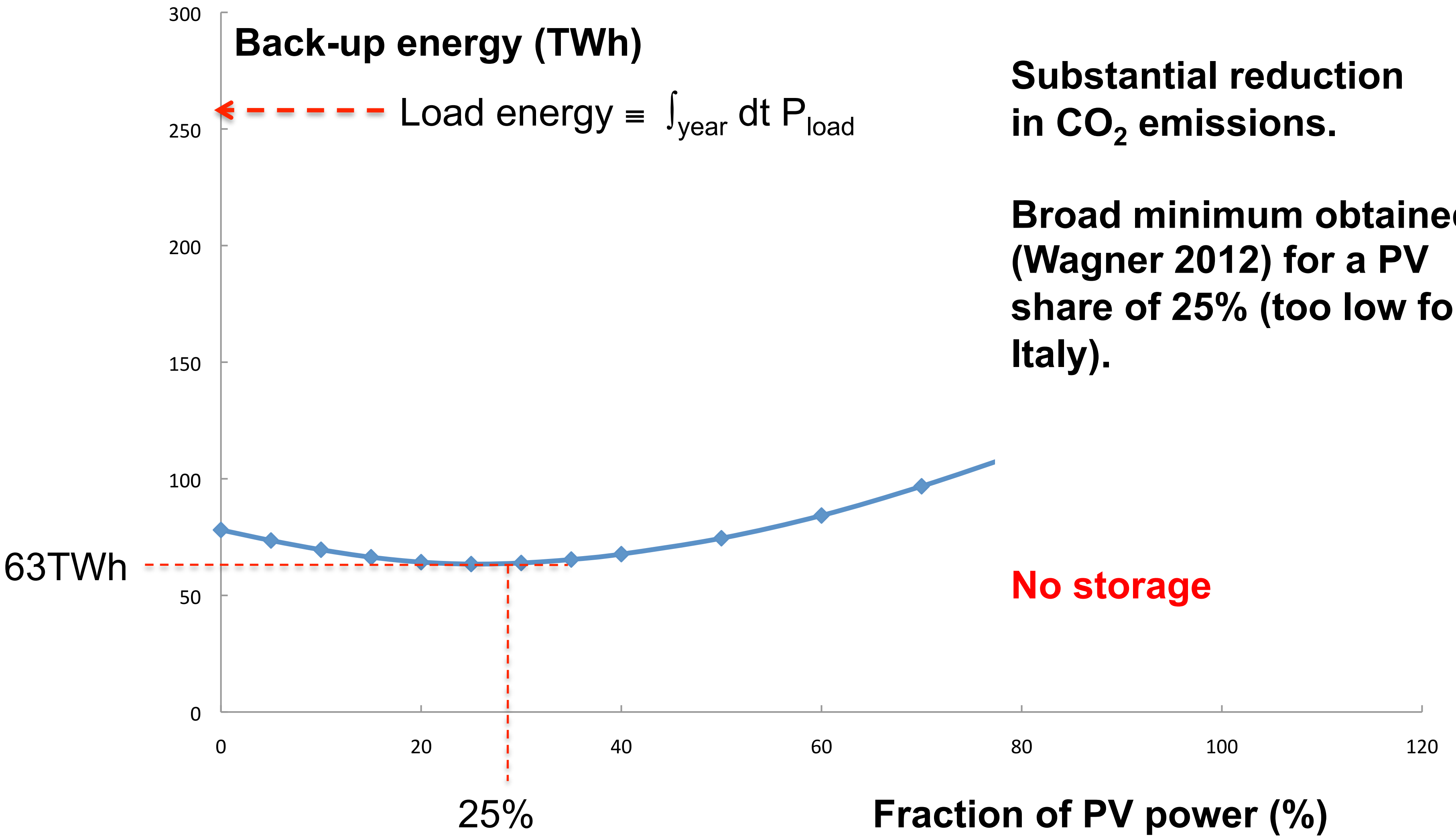
Load vs. time



Duration curve



Back-up energy substantially lower than load energy

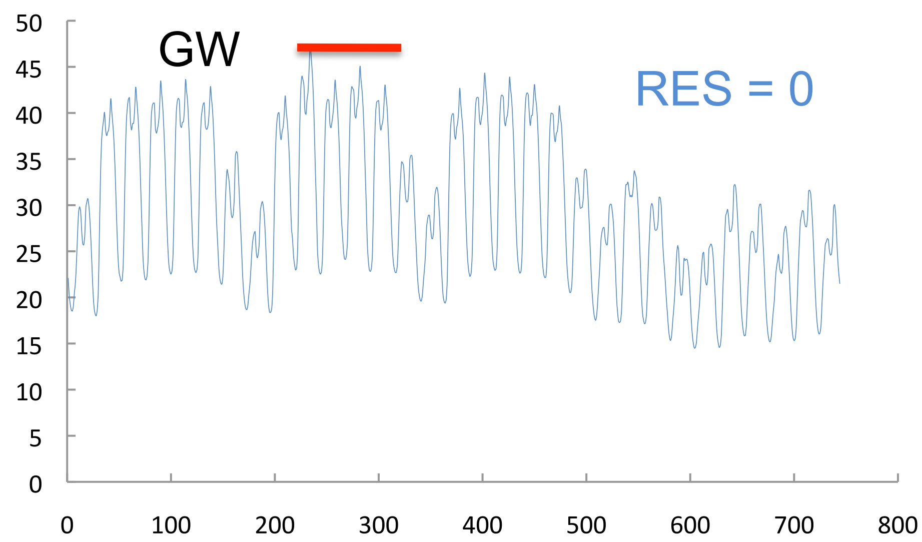


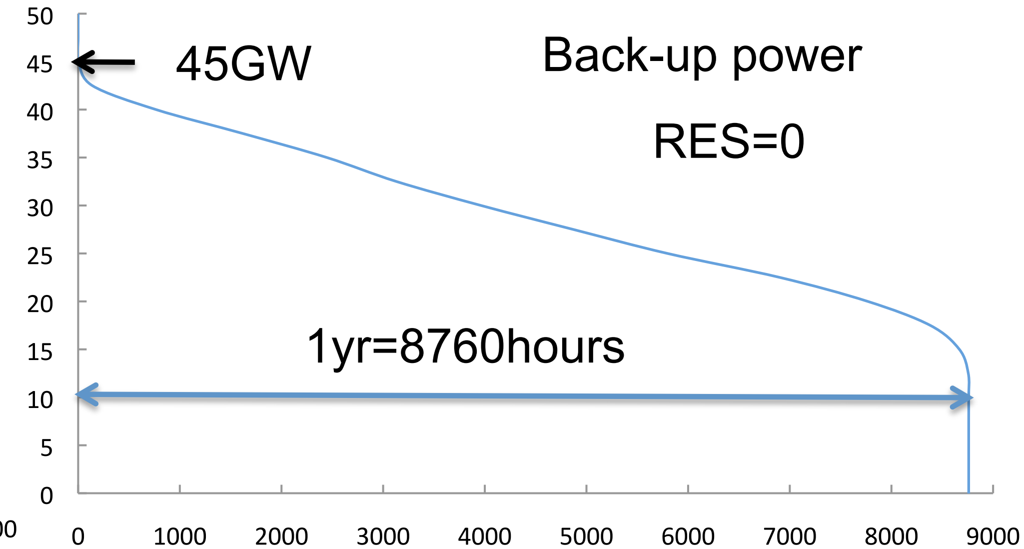
Substantial reduction in CO_2 emissions.

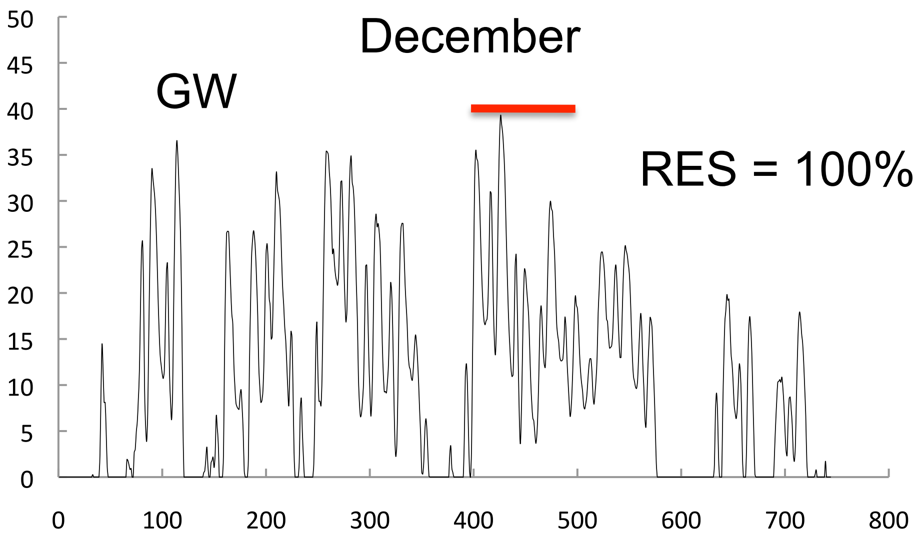
Broad minimum obtained (Wagner 2012) for a PV share of 25% (too low for Italy).

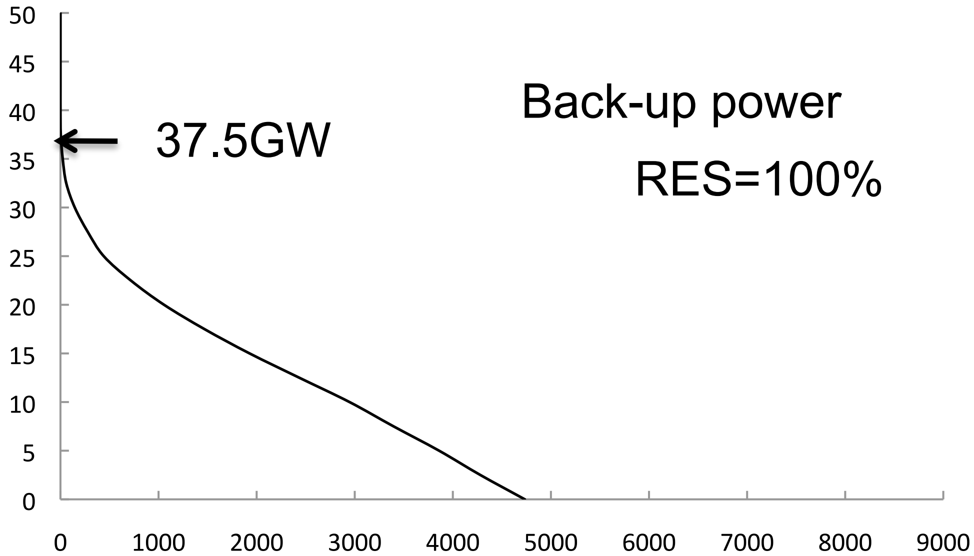
No storage

Back-up power is only slightly reduced and used at low capacity factor

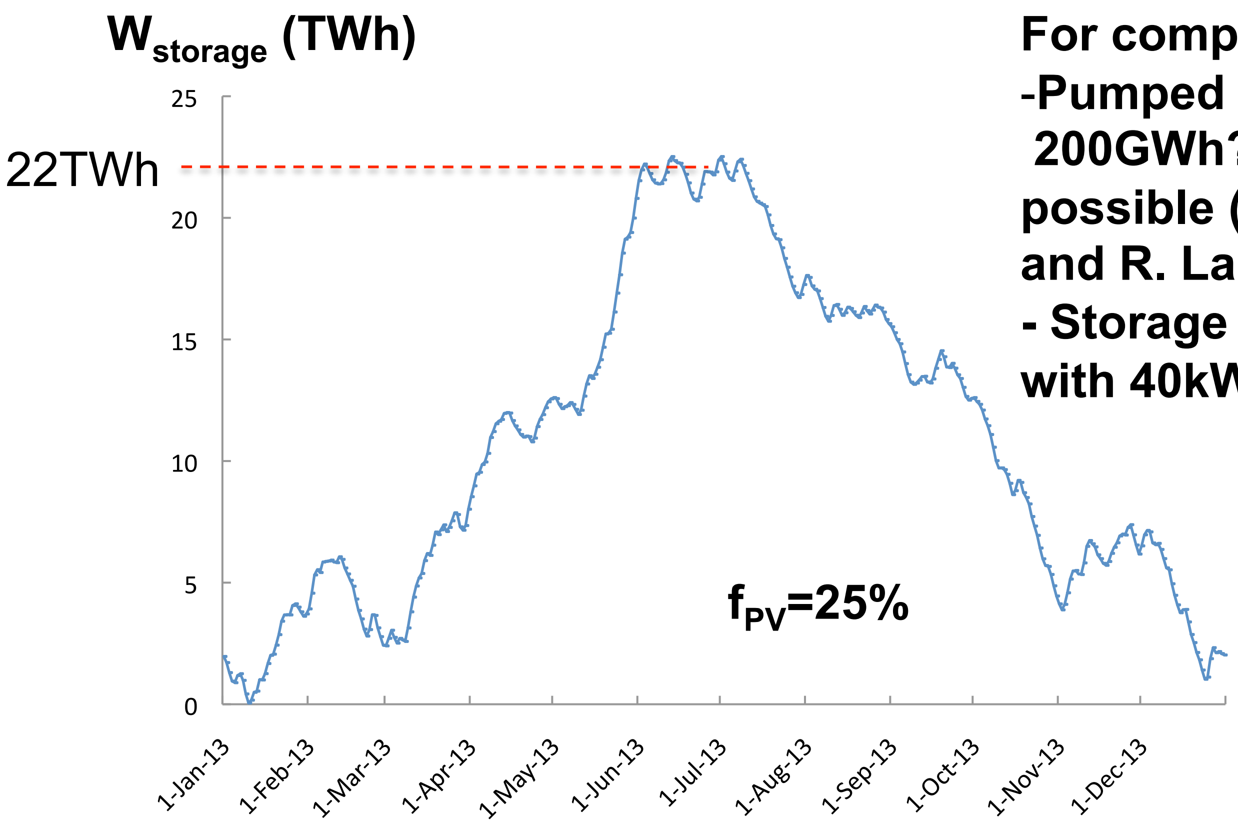








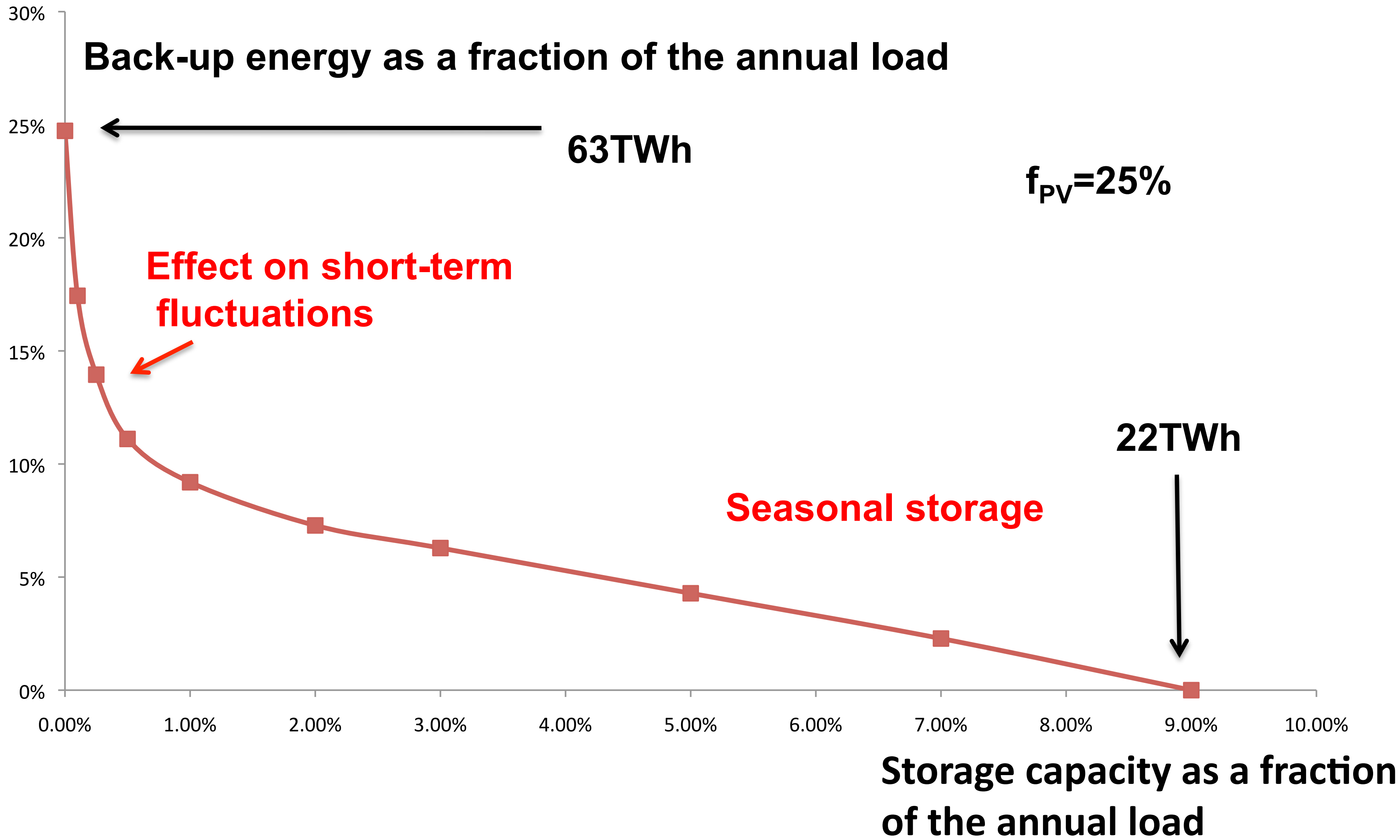
A large seasonal storage capability required to avoid the back-up power



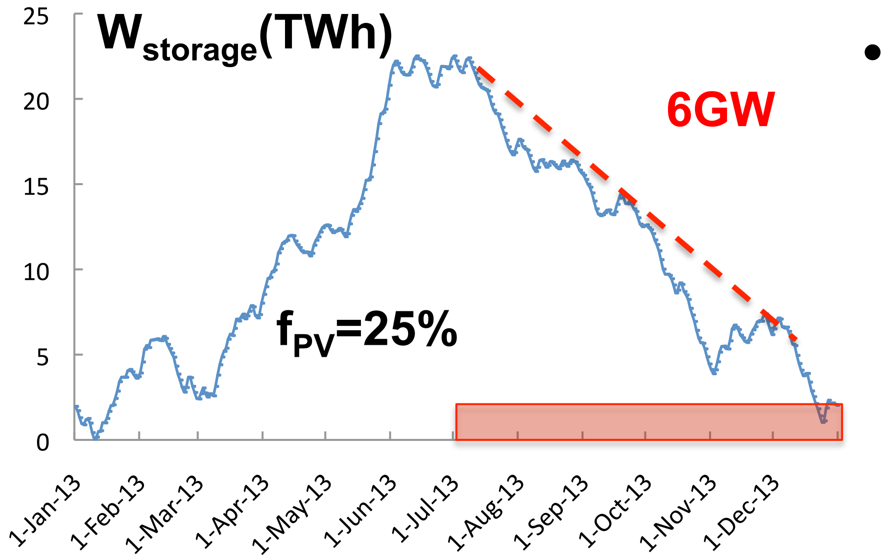
For comparison:
-Pumped storage capacity 200GWh? Pumped storage 4-7TWh possible (Gimeno-Gutiérrez and R. Lacal-Arántegui, 2013)
- Storage of 36M electric cars with 40kWh batteries ~ 1.5TWh

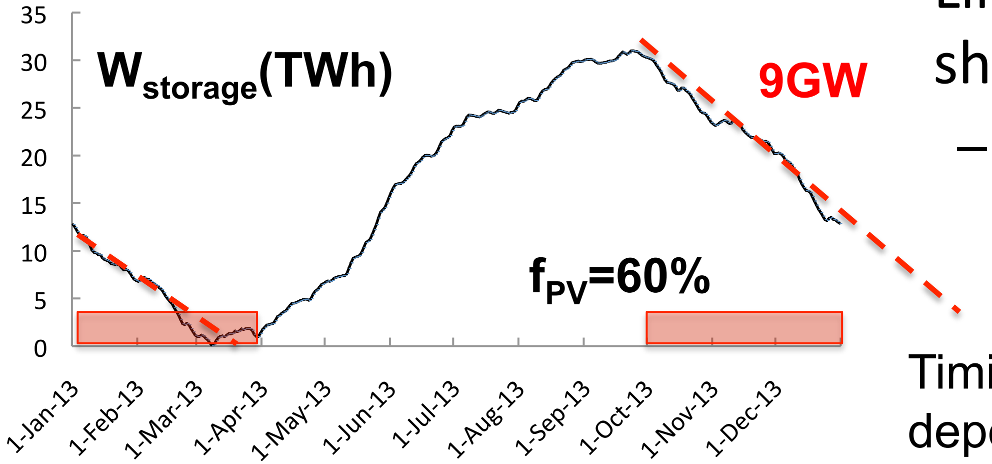
$$dW_{storage}/dt = P_{PV}+P_{wind}-P_{load}$$

Storage is effective in reducing back-up energy



Use of base-load + storage

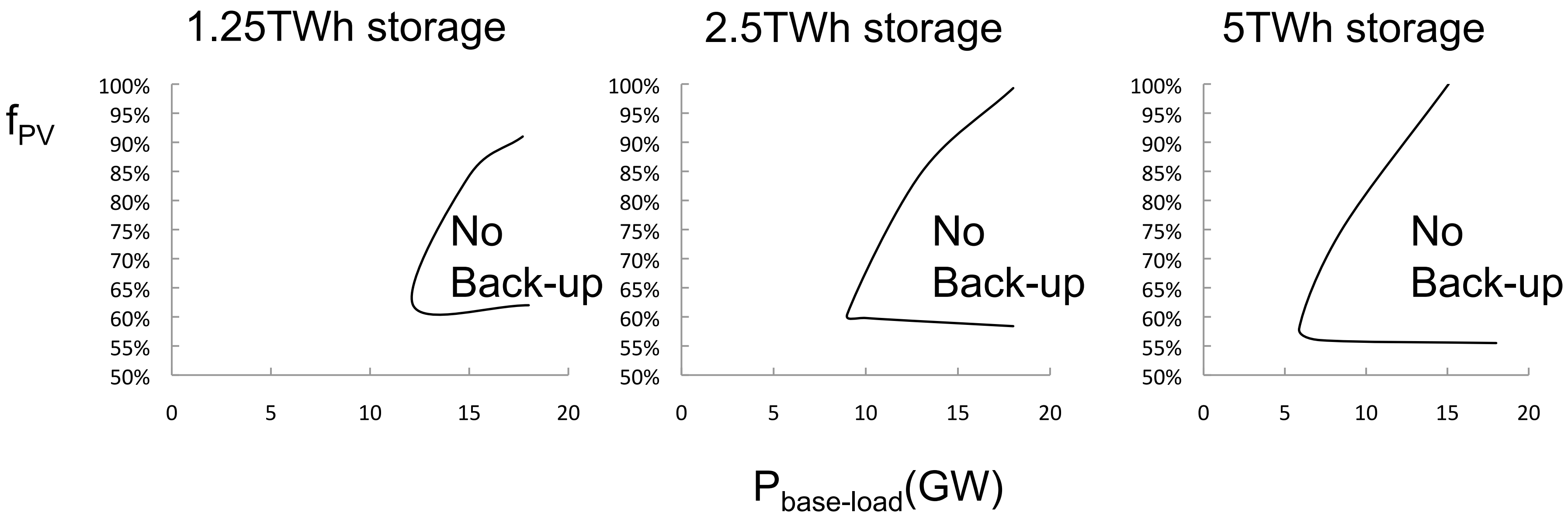




- Replace high-power and on demand back-up systems with a moderate (~10GW) constant pre-defined base-load power during the low RES production season.
  - Substantial thermal power reduction
  - Use at high capacity factor
- Limit storage to cope with the short-term fluctuations
  - Amount of storage feasible with present day technologies

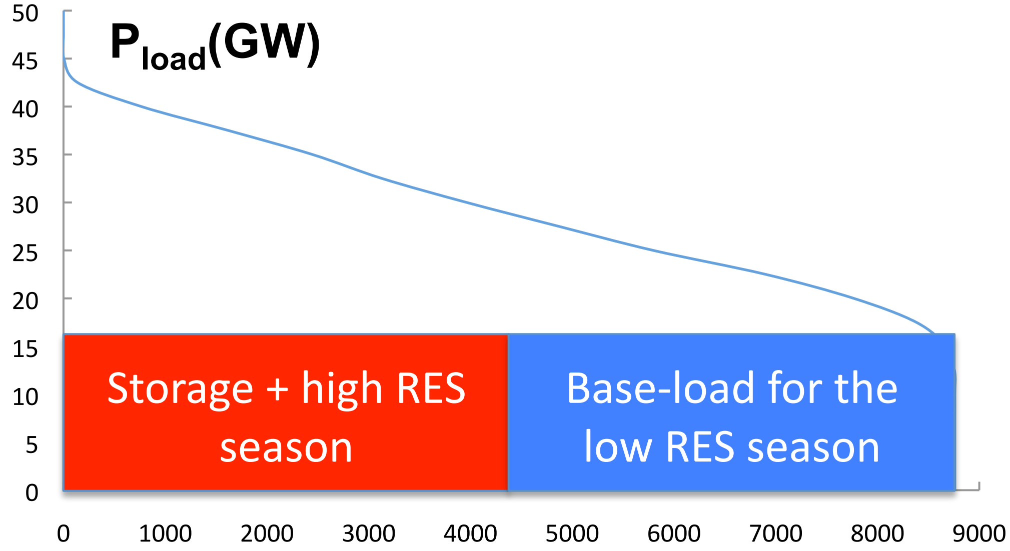
Timing of $P_{base\text{-}load}$–on phase depends on PV share.

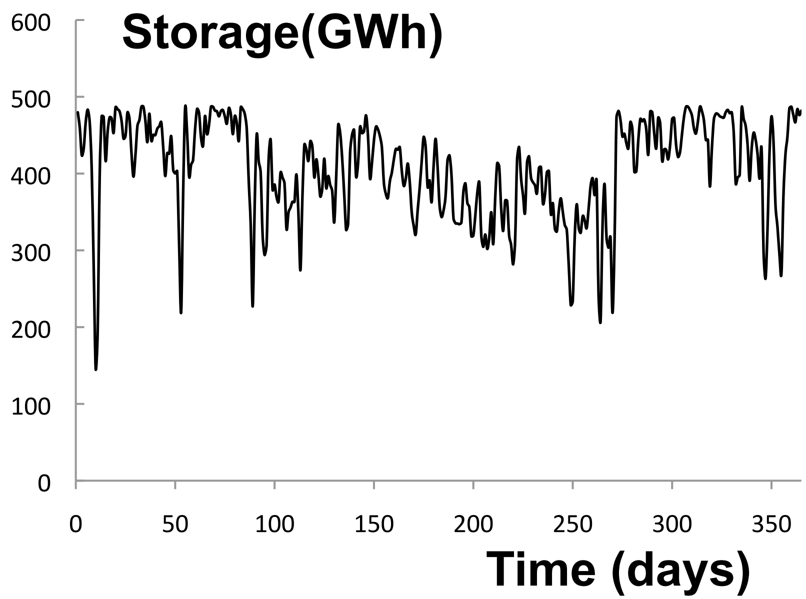
Use of base-load + storage



- Strategy effective for PV share 60%-90% - OK for Italy

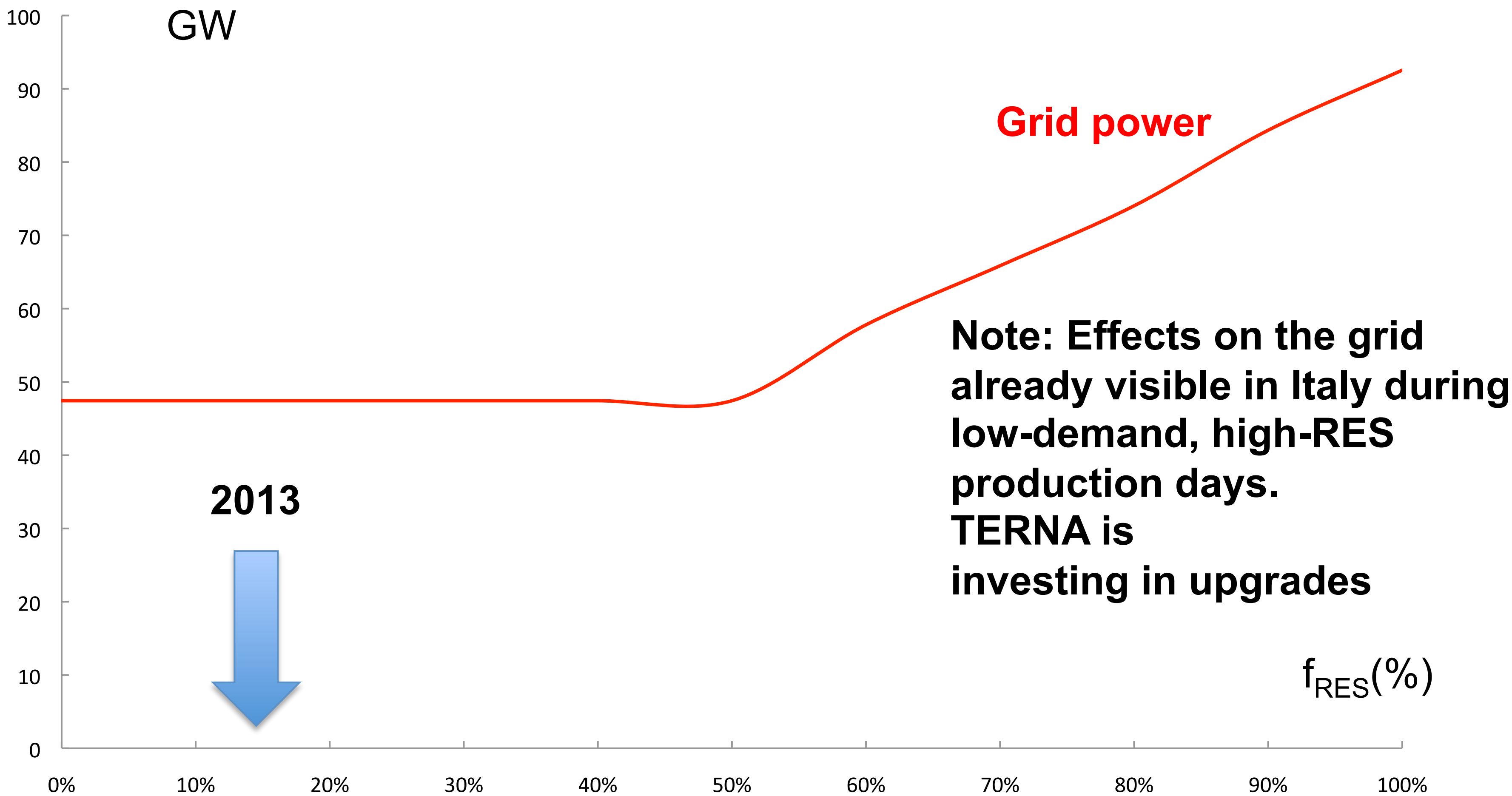
Use of base-load + storage





- Summary
  - Substantial reduction of the non-RES power to ~10-15GW and use with high capacity factor.
  - Strategy effective already at moderate storage capacity (~1TWh).
  - Base-load energy ~10-20% of the load energy.

Power to be managed by the grid increases as RES share increases



Conclusions

- Integration of intermittent RES is challenging and requires infrastructure investments. Low reduction of back-up power with no storage.
- Storage capacity to cope with seasonal fluctuations 20-30TWh – beyond present capabilities.
- Scenarios with 100% RES production possible:
  - Base-load power ~10-15GW for the low-RES season;
  - Storage capacity ~1TWh to average over the short term fluctuations – feasible with present technologies
  - PV share 60-90% - ok for Italy
- Substantial impact on the grid expected for RES share above 40%.