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 match annual electricity demand.
• Hydroelectric and geothermal generation at 2013 values
• With this input evaluate for each 1h time interval:
  – the back-up power \( P_{\text{backup}} \equiv P_{\text{load}} - P_{\text{PV}} - P_{\text{Wind}} \)
  – the back-up energy \( \equiv \int_{\text{year}} dt \, P_{\text{back-up}} \)
  – If \( P_{\text{backup}} < 0 \) define \( P_{\text{surplus}} = - P_{\text{backup}} \)
• Free parameters: storage capacity and PV share
Back-up energy substantially lower than load energy

Substantial reduction in CO₂ emissions.

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

Load energy $= \int_{\text{year}} dt P_{\text{load}}$

63 TWh

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

\[ \frac{dW_{\text{storage}}}{dt} = P_{\text{PV}} + P_{\text{wind}} - P_{\text{load}} \]
Storage is effective in reducing back-up energy

Back-up energy as a fraction of the annual load

Storage capacity as a fraction of the annual load

Seasonal storage

Effect on short-term fluctuations

63TWh

$f_{PV}=25\%$

22TWh
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 $P_{\text{base-load-on}}$ 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

Note: Effects on the grid already visible in Italy during low-demand, high-RES production days. Terna is investing in upgrades.
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%.