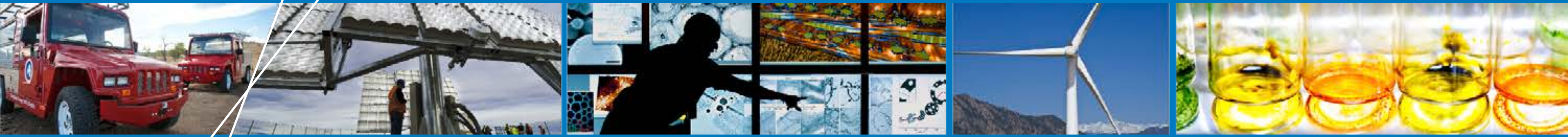
Wind and Solar Energy Curtailment Practices



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Goals of Project

Source: NREL PIX/16037

- **To better understand curtailment practices and experience**
- **Develop case studies and synthesize lessons on effective practices**
- **Key areas of focus**:
  - Magnitude of curtailment
  - Reasons for curtailment
  - Compensation practices
  - Mechanisms for implementing curtailments
  - Practices for minimizing curtailment

Approach

Source: NREL PIX/20423

- Conduct interviews with utilities and ISOs
- Document experience of utilities, primarily in WECC
- Prepare case studies:
  - MISO
  - ERCOT
  - BPA/Northwestern Utilities
  - SPP
  - Southwestern Utilities
- Synthesize key issues and experience

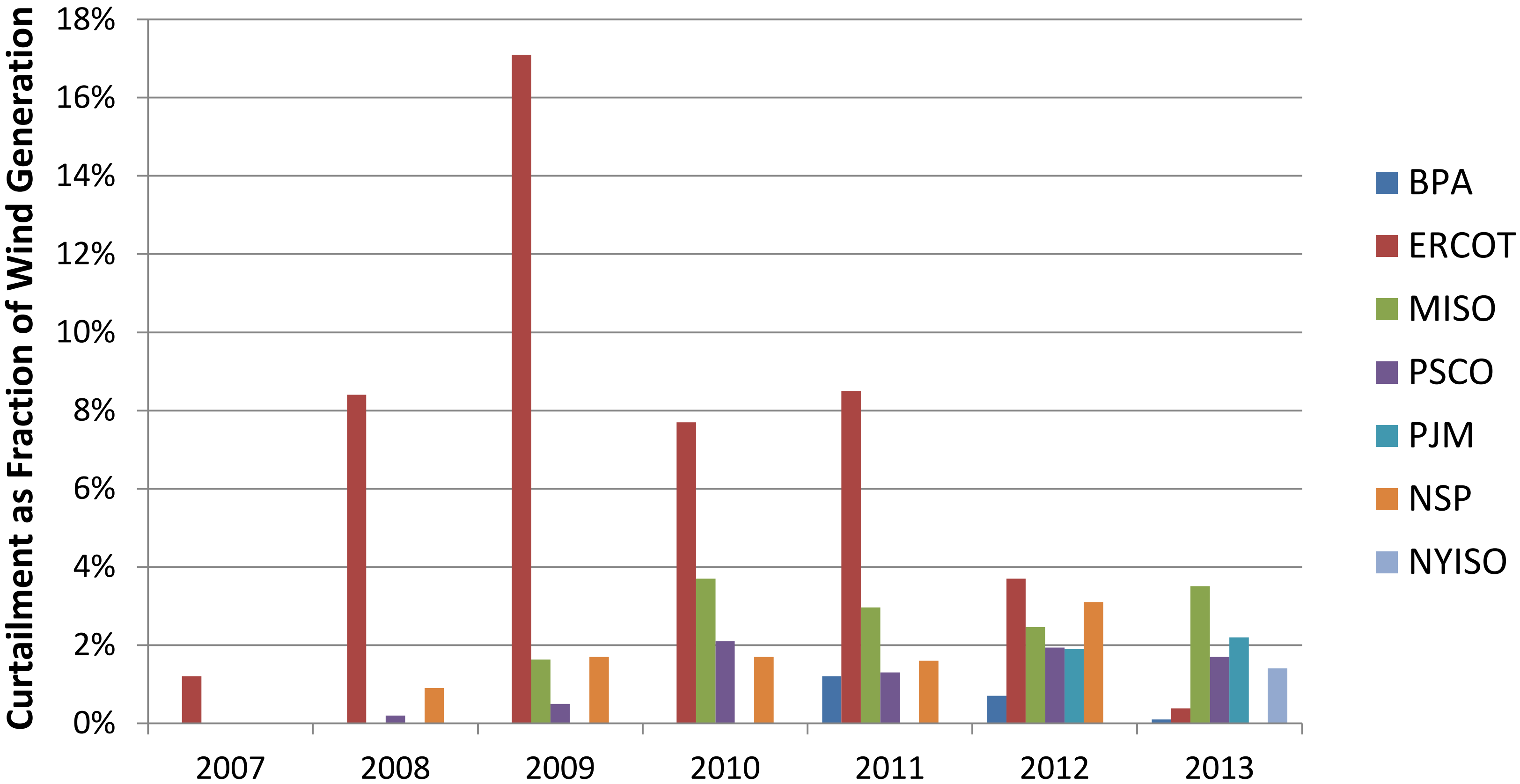
Interviews Conducted

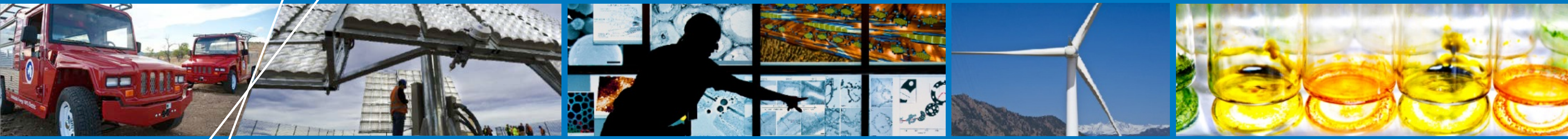
- Alberta Electric System Operator - Jacques Duchesne
- Arizona Public Service - Ronald Flood
- Bonneville Power Administration - Bart McManus
- California Independent System Operator - Clyde Loutan
- Electric Reliability Council of Texas - David Maggio
- Hawaiian Electric - Marc Matsura
- ISO New England - Stephen Rourke, Eric Wilkinson
- Midcontinent Independent System Operator - Kris Ruud
- NV Energy - Rich Salgo
- PacifiCorp - John Apperson
- Puget Sound Energy - Josh Jacobs
- Salt River Project - Mark Avery, David Crowell
- Southwest Power Pool - Don Shipley
- Tucson Electric Power - Ron Belval, Sam Rugel, Carmine Tilghman
- Xcel - Drake Bartlett
- Formerly Iberdrola - Justin Sharp
- Renewable Northwest Project, Dina Dubson
- Iberdrola, Gerald Froese
- ISO-NE - Ed McNamara, VPSB
- PJM, Ken Schuyler, Dave Souder

Curtailment Levels

Curtailment has generally been 4% of wind generation or less

ERCOT has been exception in earlier years





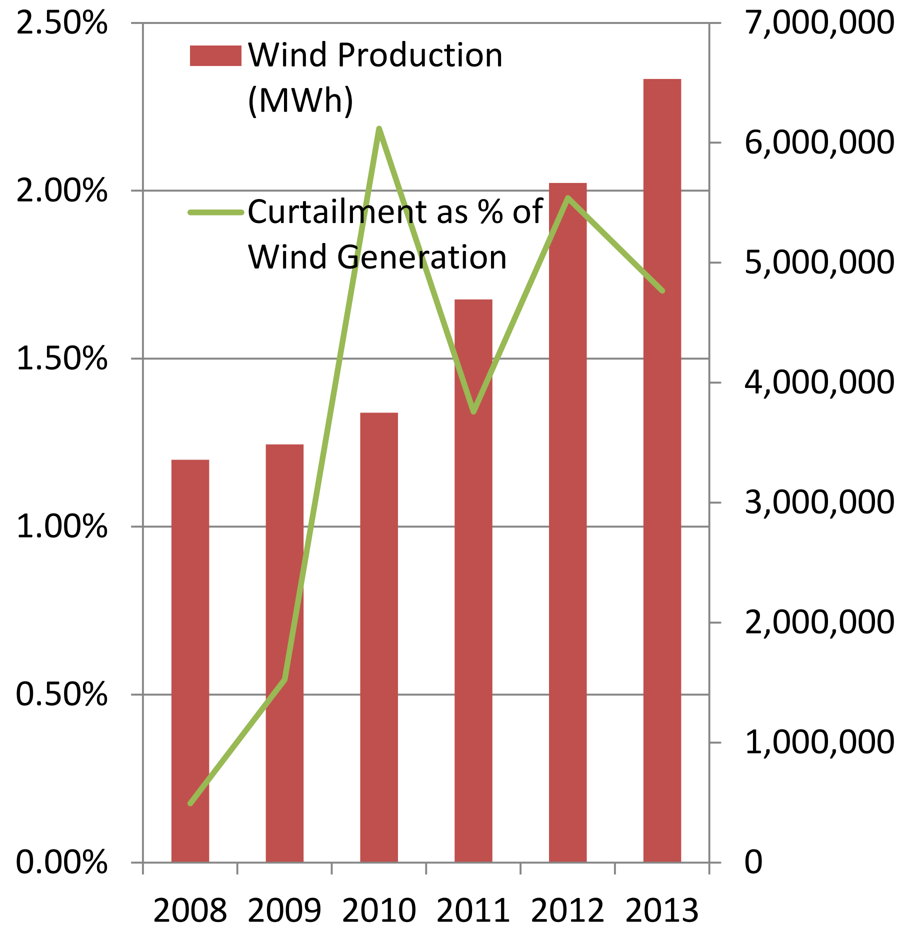
Case Studies

Xcel Energy/PSCO

Experience

- Wind grew from 3.7 to 6.5 million MWh between 2010 and 2013; curtailment declined slightly over period
- Mitigation measures used to integrate wind:
  - Improved forecasting
  - Cycling fossil units
  - Put wind on AGC; use curtailed units for up reserves

Curtailment vs. Wind Output



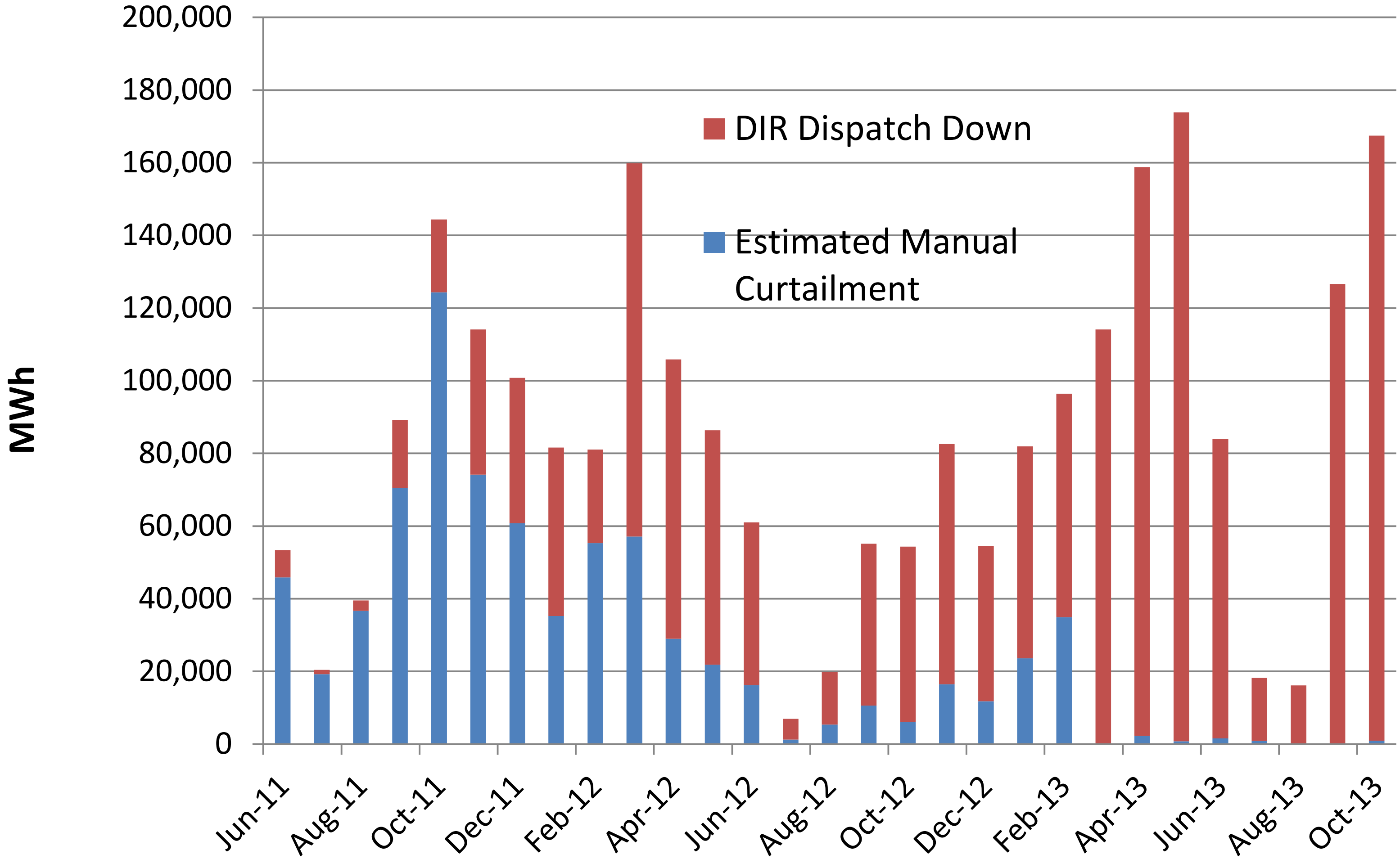
SPP Curtailment

- Wind capacity doubled in 2012 representing 7 GW of 64 GW peak
- Primary cause of curtailments: Insufficient transmission—wind on-line ahead of planned transmission upgrades
- Some wind generators: curtailment is 40% to 50% of potential
- Manual curtailments prolong events
- Three phases of curtailment mitigation
    1. Near-term: Automate (requires contract renegotiation)
    2. Medium (March 2014): Move to market-based approach, like MISO
    3. Long-term (mid 2014-2015): New transmission

MISO

- **MISO has more than 12 GW of wind capacity and a peak demand of 98 GW**
- **Mid 2011, Dispatchable Intermittent Resource (DIR) protocol launched**
  - Requires wind plants (April 2005 and later) to bid into real-time market
  - Automated dispatch-down process improves efficiency; alleviates burden on grid operator; same for all generators
- **Prior to DIR, MISO used only manual curtailments to address congestion**
  - Operators used over 1,000 times in 2009 and 2010

MISO Manual Curtailments & Dispatch Down



MISO estimated energy manually curtailed in MWh versus dispatched down

Source: Ruud 2014; McMullen 2013

MISO Curtailment Statistics

MISO Estimated Manual Curtailment and Dispatch Down

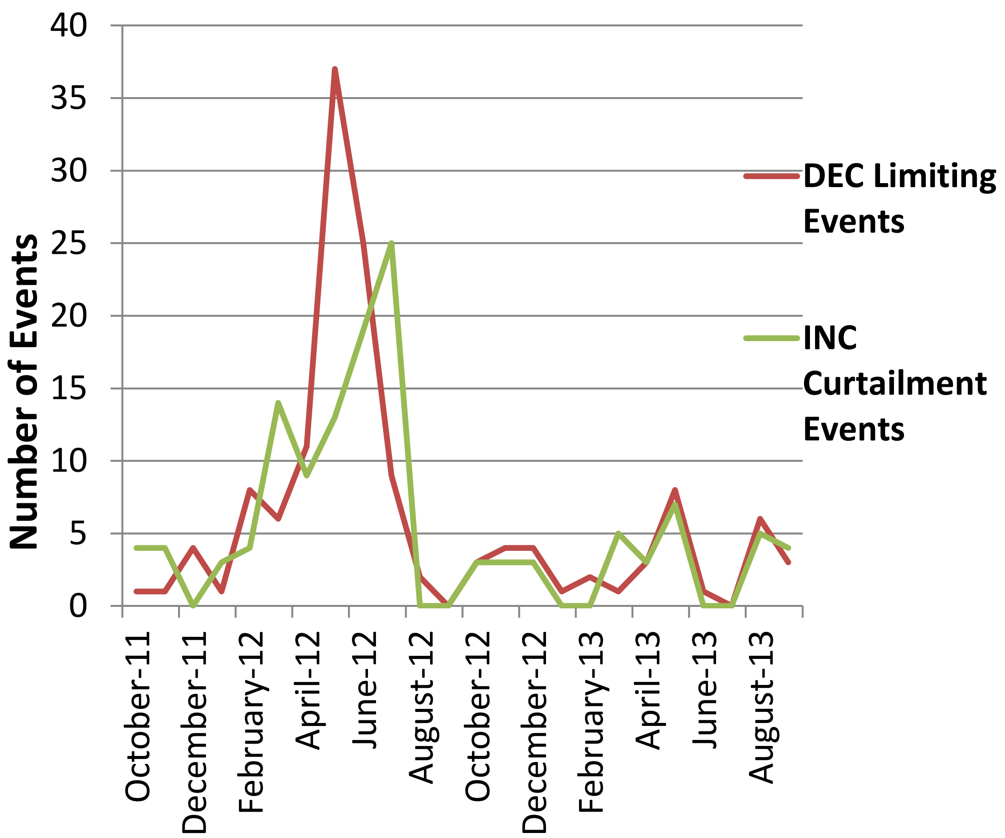
	2009	2010	2011	2012	2013 (Oct)
Number of Wind Curtailments	1,141	2,117	2,034	889	n/a
Estimated Curtailment (MWh)	292,000	824,000	720,000	266,000	65,010
Duration (hours)	8,005	19,951	20,365	10,430	n/a
DIR Dispatch Down (MWh)	N/A	N/A	130,296	582,653	972,580

Source: Ruud 2014; McMullen 2013

BPA Curtailment

- BPA has 4,500 MW of wind in BA and peak demand of 11,500 MW, some wind resources have shifted out of the BA recently.
- There are two types of curtailments:
  1. Curtailments caused by exhaustion of balancing reserves causing wind to curtail to schedule or limit output to production level (Dispatch Standing Order 216)
  2. Curtailments that result from seasonal hydro oversupply (Oversupply Management Protocol)
- BPA has been modifying its curtailment protocols and exploring measures to help reduce curtailment, including:
  - faster scheduling, better use of forecasts, and improved methods of committing and de-committing reserves.

BPA Curtailment Statistics



DSO 216 balancing curtailments as a result of both limiting and curtailment events.

Curtailments Under OMP and its Predecessor Environmental Redispatch

2011	97,200 MWh
2012	49,700 MWh
2013	0 MWh

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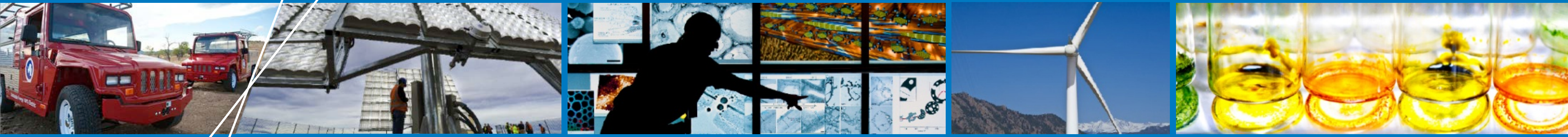

Synthesis and Conclusions

Reasons for curtailment

Transmission Constraints

- Transmission builds lagging wind development
- Local transmission congestion
- Transmission line outages and maintenance (minor)

System Balancing

- Periods of oversupply and low loads
- In wholesale markets, wind participating in dispatch (dispatched down)
- Environmental constraints on hydropower units
- Ramping - to slow down a rapid change in wind output

Curtailment Protocols

Signaling

- Signaling methods vary; mix of manual vs. automated
- Manual signaling often extends curtailment periods
- In wholesale markets, RE must follow basepoint instruction down
- A few utilities place wind on AGC to quickly control output

Curtailment Order

- Influenced by market design, contracts, and plant economics, as well as cause (congestion vs. oversupply)
- Often based on economics
- For congestion, order based on effectiveness in alleviating constraint
- In Hawaii, order is based on installation date

Compensation

- **Compensation for curtailment varies; contracts are changing**
- **A number of utilities offer take or pay contracts or have had these historically**
  - Utilities increasingly including uncompensated hours in contracts or placing limits
- **New market mechanisms such as in MISO and SPP are requiring contract changes**
- **In wholesale markets, sometimes no compensation outside of PPAs; others compensate with make whole payments when curtailed from schedule**

Mitigation Measures

Measures to Help Reduce Curtailments

- Forecasting
- Transmission Planning
- Reserves Management
- Strategies to Address Ramping
- Market Integration and Negative Bidding
- Automation

Source: NREL PIX/16037

Conclusions

- **In the largest markets for wind power, curtailments are declining while wind power on the system increases.**
- **Curtailment levels have generally been 4% or less of renewable energy generation where it has occurred.**
- **Definitions of curtailment and data availability vary.**
  - New market-based protocols obscure levels
  - Lack of uniformity in data collection
- **Curtailment order is often based on plant economics or ability to alleviate local congestion.**
- **Compensation and contract terms are changing as curtailment becomes of greater concern.**
  - Increasingly curtailment hours are negotiated;
  - Greater sharing of risk among the generator and off-taker.

Conclusions (cont.)

- **Automation can reduce curtailment levels.**
  - Manual processes can extend curtailments because of implementation time and hesitancy to release units from curtailment orders.

- **Market solutions that base dispatch levels on economics offer transparency and automation in curtailment procedures, which apply equally to all generators.**

- **Curtailed renewable resources can provide ancillary services to aide in system operations.**

- **A variety of solutions are being used to reduce curtailments:**
  - transmission expansion and interconnection upgrades;
  - operational changes such as forecasting and increased automation;
  - better management of reserves and generation.

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Thank you

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