



Benefit Assessment in Economic Evaluation of Transmission Expansion

SSG-WI Workshop Session 3

Economic Evaluation of Transmission Expansion

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CAISO Market Analysis

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Presentation Outline

- **Concepts of economics surpluses/benefits**
- **Identifying and calculating economic benefits of transmission expansion for various market participants**
- **Evaluating economic transmission expansion project: benefit tests**
- **Overview of example case study**



CAISO TEAM

- **Assessment method presented here is part of TEAM (Transmission Economics Assessment Methodology) developed for CAISO.**
- **For more detailed description, please see the CAISO TEAM Report at**
<http://www1.caiso.com/docs/2003/03/18/2003031815303519270.html>
- **Method can be extended to other systems.**



Major Challenges to Valuing Transmission Upgrades in Wholesale Market Regime

- **How do strategic suppliers bid both before and after the transmission upgrade?**
- **What are the appropriate measures of transmission expansion benefits to all market participants?**
- **Whose benefit should be included in the evaluation of economic-driven transmission project for both private investment and regulated investment?**
- **How should the CAISO evaluate an economic-driven transmission upgrade project?**



Benefit Measures in Vertical Integrated Regime vs. Wholesale Market Regime

- **VI Regime: Production Cost Saving**
- **WM Regime:**
 - **Production Cost Saving**
 - **Societal Benefit**
 - **Consumer Benefit**
 - **Producer Benefit**
 - **Transmission Owner Benefit (or FTR/CRR Holder Benefit)**
 - **Monopoly Rent Benefit**
 - **Competitive Rent Benefit**
 - **Ratepayer Benefit**
 - **Participant Benefit**
 - **Etc.**



Economic Surpluses in Wholesale Market Regime

- **Consumer Surplus (CS)** is the difference between consumers' willingness to pay and their payment (Cost-to-Load).

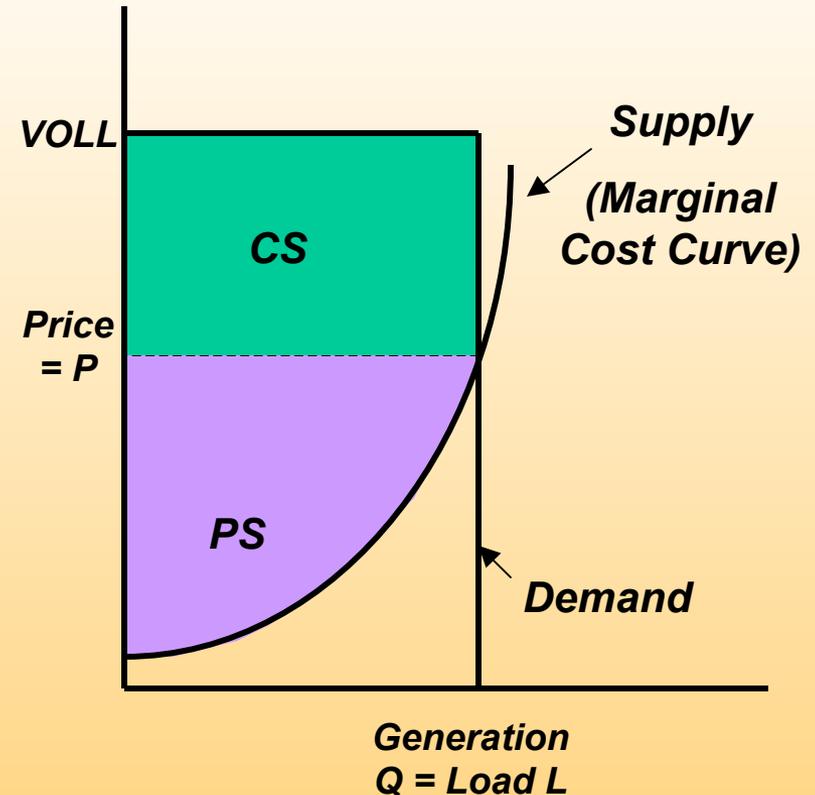
$$CS \cong (VOLL - Price) * Load$$

- **Producer Surplus (PS)** is the difference between the total payment producers received (Producer Revenue) and the total variable cost of production (Production Variable Cost).

$$PS = PR - PC$$

- **Total Surplus (TS)** is the sum of CS and PS if there is no congestion.

$$TS = CS + PS$$



**Assumption: no congestion,
no losses, no market power**



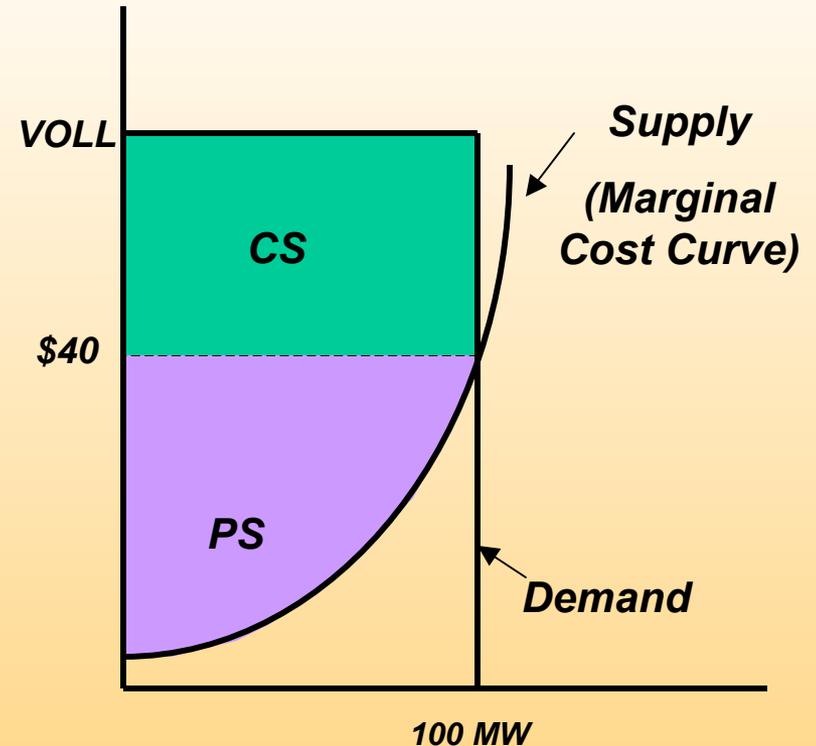
Economic Surpluses - Example

- Suppose all generators bid their marginal costs.
- There is no congestion in the system.
- Total system load and generation is 100 MW.
- Price across the system is \$40/MWh.
- VOLL is \$100/MWh.
- Total production variable cost (fuel and variable O&M) is \$2000.
- Thus

$$CS = (\$100 - \$40) * 100 = \$6000$$

$$PS = \$40 * 100 - \$2000 = \$2000$$

$$TS = \$6000 + \$2000 = \$8000$$



**Assumption: no congestion,
no losses, no market power**



Economic Surpluses --- continued

- **What if the system is congested somewhere?**
- **There exists locational price differences.**
- **Transmission owners or FTR/CRR holders get paid congestion revenue.**
- **Congestion Revenue (CR) is the difference between what consumers pay (Cost-to-Load) and what generators receive (Producer Revenue).**

$$CR = CTL - PR$$

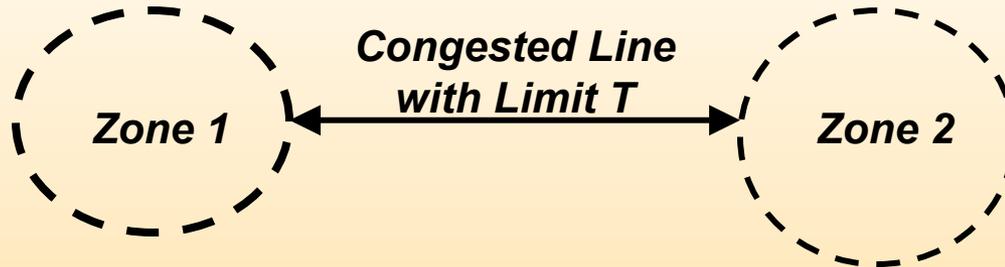


Economic Surpluses --- continued

- **Congestion Revenue sometimes is called Congestion Management Charge or Congestion Usage Charge.**
- **Whatever the name it is called, this is the part of the monies that goes back to transmission owners or FTR/CRR holders of congested lines so that ISO can remain cash neutral.**



A 2-Zone Example



Zone 1: Importing Zone (due to resource inadequacy or more expensive generation)

Zone 2: Exporting Zone (due to abundant generation or cheap generation)

T: Power transfer limit between two zones

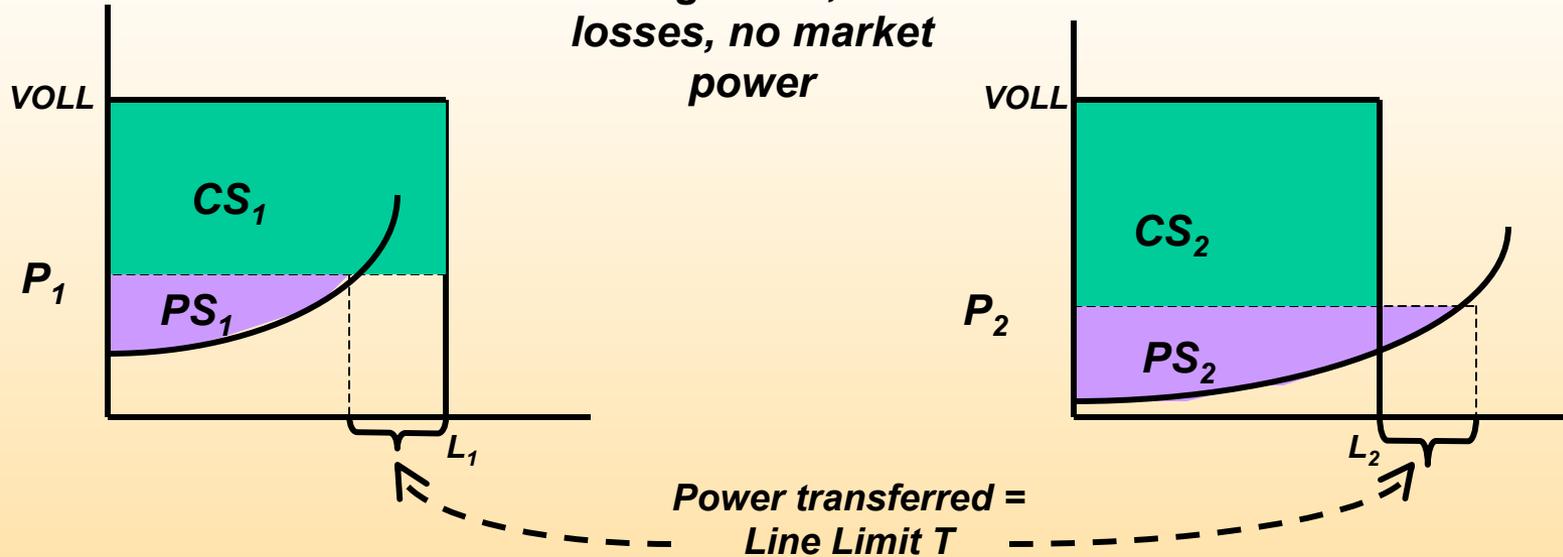
Line can be congested.



1 = Importing Zone

Case assumptions:
congestion, no
losses, no market
power

2 = Exporting Zone



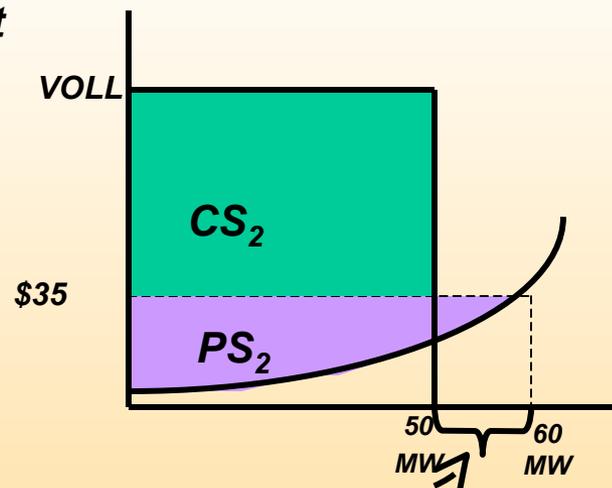
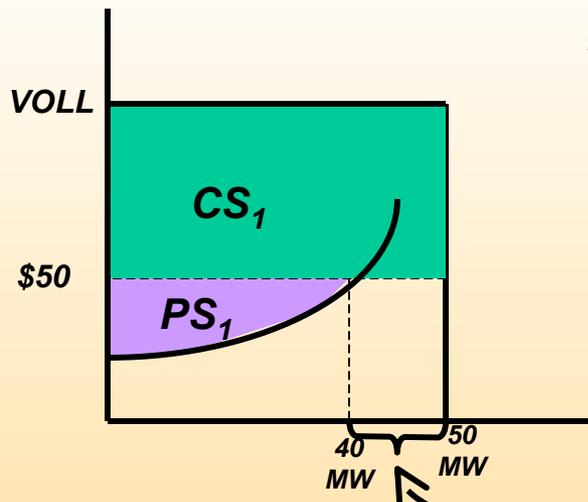
- $CR = Total\ Cost\ to\ Load - Total\ Producer\ Revenue$
 $= (CTL_1 + CTL_2) - (PR_1 + PR_2)$
- Equivalently, CR can also be calculated as $Line\ Flow * (P_1 - P_2)$
- Total Surplus is $TS = CS + PS + CR$.



1 = Importing Zone

Case assumptions:
congestion, no
losses, no market
power

2 = Exporting Zone

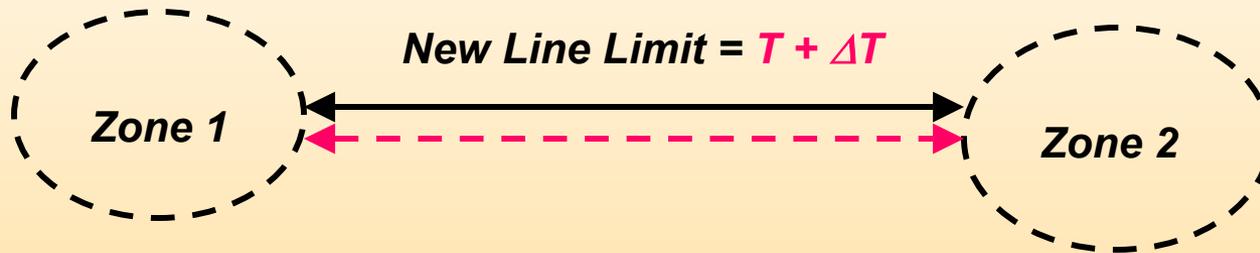


10 MW is transferred

- Suppose $L_1 = 50$ MW, $L_2 = 50$ MW, $P_1 = \$50/\text{MWh}$, $P_2 = \$35/\text{MWh}$,
 $PC_1 = \$1300$, $PC_2 = \$800$, $Q_1 = 40$ MW, $Q_2 = 60$ MW, and $T = 10$ MW
- $CS = CS_1 + CS_2 = (\$100 - \$50) * 50 + (\$100 - \$35) * 50 = \$5,750$
- $PS = PS_1 + PS_2 = (\$50 * 40 - \$1300) + (\$35 * 60 - \$800) = \$2,000$
- $CR = (\$50 - \$35) * 10 = \$150$
- $TS = CS + PS + CR = \$7,900$



If we plan to expand the line limit to $T + \Delta T$, how are we going to measure the economic expansion benefit?



Line can still be congested after expansion.

Generators in Zone 1 produce less output than without expansion.

Generators in Zone 2 produce more output than without expansion.

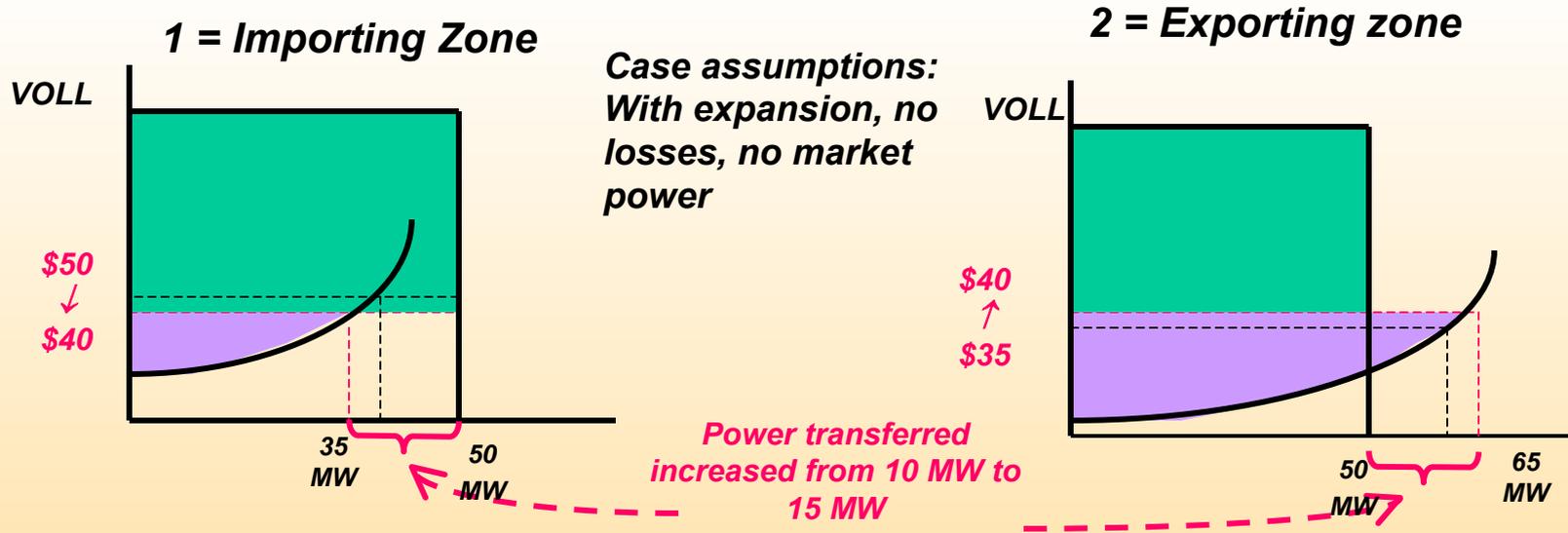
Price in Zone 1 may go down.

Price in Zone 2 may go up.

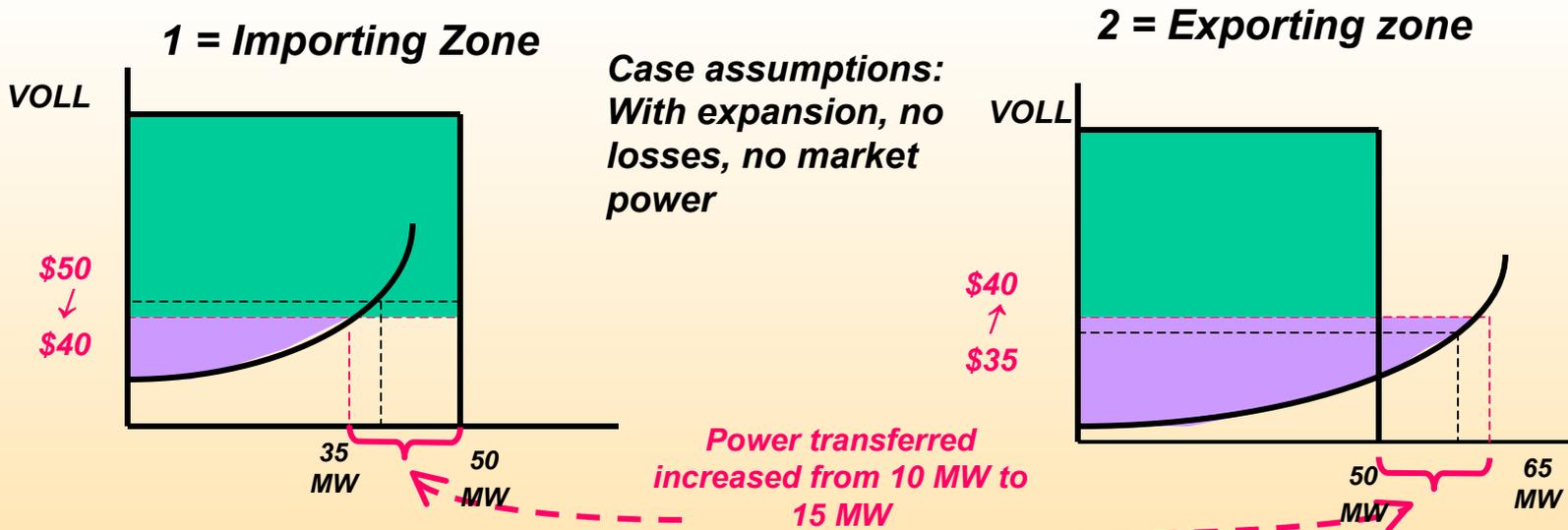


How do we calculate the benefit of a transmission upgrade?

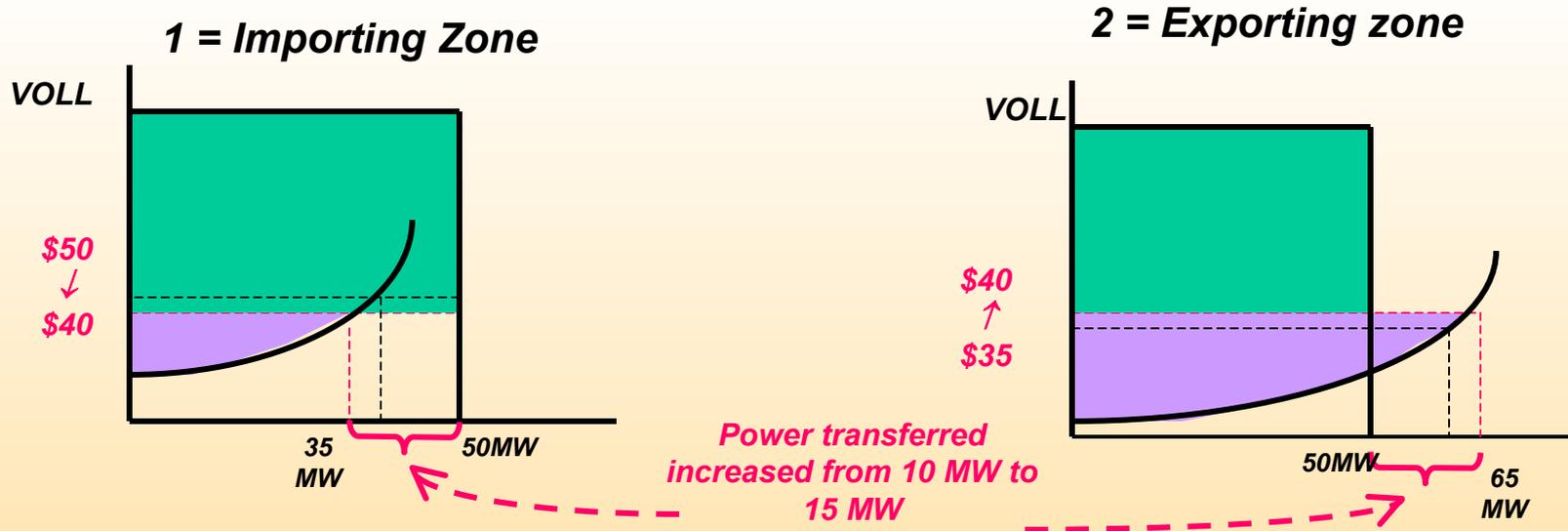
- **Compute all surpluses without and with expansion for all market participants in all regions.**
- **Subtract surplus without expansion from surplus with expansion.**
- **Obtain the net impact of transmission expansion on various market participants in various regions.**



- Suppose the line is expanded by 20 MW and is no more congested.
- System price goes down to \$40/MWh, system production cost goes down to \$2,000.
- Total consumer surplus with expansion is
 $CS' = (\$100 - \$40) * 50 + (\$100 - \$40) * 50 = 6,000$
- Total producer surplus with expansion is
 $PS' = (\$40 * 35 + \$40 * 65) - \$2,000 = \2000
- Since the line becomes no more congested with expansion, congestion revenue is \$0 with expansion. $CR' = (\$40 - \$40) * 15 = \$0$
- Total surplus with expansion is $TS' = \$6000 + \$2000 + \$0 = \8000



- In this example, consumers as a whole benefit from expansion.
 $\Delta CS = \$6,000 - \$5,750 = \$250$
- Producers as a whole do not benefit from expansion.
 $\Delta PS = \$2,000 - \$2,000 = \$0$
- Since the line becomes no more congested with expansion, TOs (or CRR Holders) are a net loss. $\Delta CR = \$0 - \$150 = -\$150$
- Total expansion benefit is $\Delta TS = \$250 + \$0 - \$150 = \100



- Where does transmission expansion benefit come from?
- From more efficient generation utilization (dispatch).
- In this example, more cheaper generation in Zone 2 is able to serve load in Zone 1 due to transmission expansion.
- Total production variable cost is reduced as the result of expansion.
- Fundamentally, total transmission expansion benefit equals to total reduction of production variable cost (if load is not price sensitive).

- In this example, $\Delta PC = \$2000 - \$2100 = -\$100$
 $\Delta TS = \$250 + \$0 - \$150 = \100



- Market participants in different zones are impacted differently by expansion.
- Suppose with expansion, $PC_1' = \$1250$, $PC_2' = \$750$, $Q_1' = 35 \text{ MW}$, $Q_2' = 65 \text{ MW}$.
- Zone 1: Consumers benefit from expansion. $\Delta CS_1 = (\$50 - \$40) * 50 = \$500$
Producers do not benefit from expansion.
 $\Delta PS_1 = (\$40 * 35 - \$1250) - (\$50 * 40 - \$1300) = \$150 - \$700 = -\$550$
- Zone 2: Consumers do not benefit from expansion. $\Delta CS_2 = (\$35 - \$40) * 50 = -\$250$
Producers benefit from expansion.
 $\Delta PS_2 = (\$40 * 65 - \$750) - (\$35 * 60 - \$800) = \$1850 - \$1300 = \$550$
- It's important to evaluate who benefit and who lose from transmission expansion.



How should we evaluate an economic transmission expansion project?

- **We need to evaluate whether the project benefits the society as a whole.**
- **We also need to evaluate whether the project benefits its funding parties or users.**
- **We focus on projects funded by regulated investment.**
- **If it is regulated investment, we need to identify who are the funding parties and users of the project.**
- **Then we can determine whose benefits to be included in project evaluation and apply evaluation criteria.**



Private vs. Regulated Investment in Wholesale Market Regime

- **Private Investment**: does not seek cost recovery from electricity customer rate base. Cost is recovered through receiving FTR/CRR on the increased transmission capacity.
- **Regulated Investment**: any ratepayer funded transmission project including private project with regulated cost recovery arrangement.
- The distinction between private and regulated investment is important because it determines whose benefit to be included in project evaluation.
- Our focus is on regulated investment. A project is recommended if it benefits its ratepayers in aggregate.
- If a private project is cost-effective to its investors, does not harm the ratepayers, and does not jeopardize the stability and reliability of the grid, we should also recommend it.



Societal Test: Does a project benefit the society as a whole?

- **A project can pass the societal test if the present value of total societal benefit from the upgrade exceeds the present value of total project cost.**
- **Total societal benefit is the sum of consumers' benefit, producers' benefit, and transmission owners' (or FTR/CRR holders') benefit across all regions.**
- **Total societal benefit from transmission expansion is equivalent to total system variable production cost savings due to expansion (when demand is irresponsive).**



Ratepayer Test: Does a project benefit its ratepayers?

- **A project can pass the ratepayer test if the present value of total ratepayer benefit from the upgrade exceeds the present value of total project cost.**
- **Calculation of total ratepayer benefit has to include all relevant ratepayers.**
- **In the CAISO case, ratepayers include all load serving entities, PTOs, and utility-retained generation in CAISO Control Area.**



Participant Test: Does a project benefit its users (market participants)?

- **A project can pass the participant test if the present value of total participant benefit from the upgrade exceeds the present value of total project cost.**
- **Calculation of total participant benefit has to include all relevant market participants.**
- **In the CAISO case, participants include all load serving entities, PTOs, utility-retained generation, and IPPs in CAISO Control Area.**



Impact of Generation Long-Term Contracts on Benefits

- **Long-term generation contracts do not affect total societal benefit from transmission expansion, because total production cost saving remains the same regardless of contract covering.**
- **Generation contract covering may have significant impact on benefit distribution among various market participants.**
- **Generation in the importing zone and load in the exporting zone can use long-term contract to hedge against potential price decrease or increase due to transmission expansion.**



- Suppose Load in Zone 1 has long-term contract with generation in Zone 1 for 10 MW at \$45/MWh.
- Thus consumers benefit in Zone 1 can be calculated as follows:

$$CS_1 = (\$100 - \$50) * 40 + (\$100 - \$45) * 10 = \$2550$$

$$CS_1' = (\$100 - \$40) * 40 + (\$100 - \$45) * 10 = \$2950$$

$$\Delta CS_1 = \$2950 - \$2550 = \$400, \text{ comparing to } \$500 \text{ without long-term contract covering.}$$

- Producer benefit in Zone 1 can be calculated as follows:

$$PS_1 = \$50 * 30 + \$45 * 10 - \$1300 = \$650$$

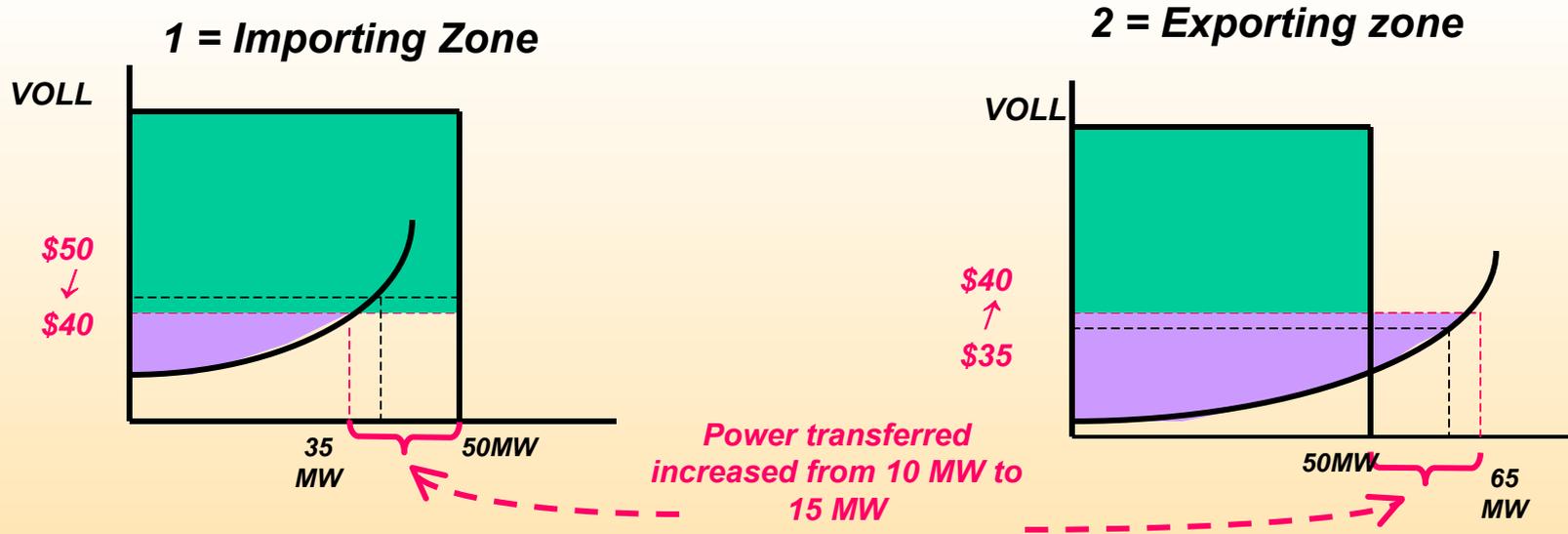
$$PS_1' = \$40 * 25 + \$45 * 10 - \$1250 = \$200$$

$$\Delta PS_1 = \$200 - \$650 = -\$450, \text{ comparing to } -\$550 \text{ without long-term contract covering.}$$



Impact of Transmission Congestion Contracts on Benefits

- **Transmission congestion contract is a financial instrument that provides a hedge against congestion price differences between zone or nodes.**
- **Transmission congestion contracts do not affect total societal benefit from transmission expansion, because total production cost saving remains the same regardless of contract covering.**
- **Transmission congestion contracts may have significant impact on benefit distribution among various market participants.**



- Suppose Load in Zone 1 has bought 10 MW of CRR with Sink in Zone 1 and Source in Zone 2.
- Load in Zone 1 has become CRR holders in this case.
- Then Load in Zone 1 is entitled to congestion revenue.
- Thus consumers benefit from transmission expansion in Zone 1 is $\Delta CS_1 + \Delta CR = (\$50 - \$40) * 50 + (\$0 * 15 - \$15 * 10) = \$500 - \$150 = \350 .



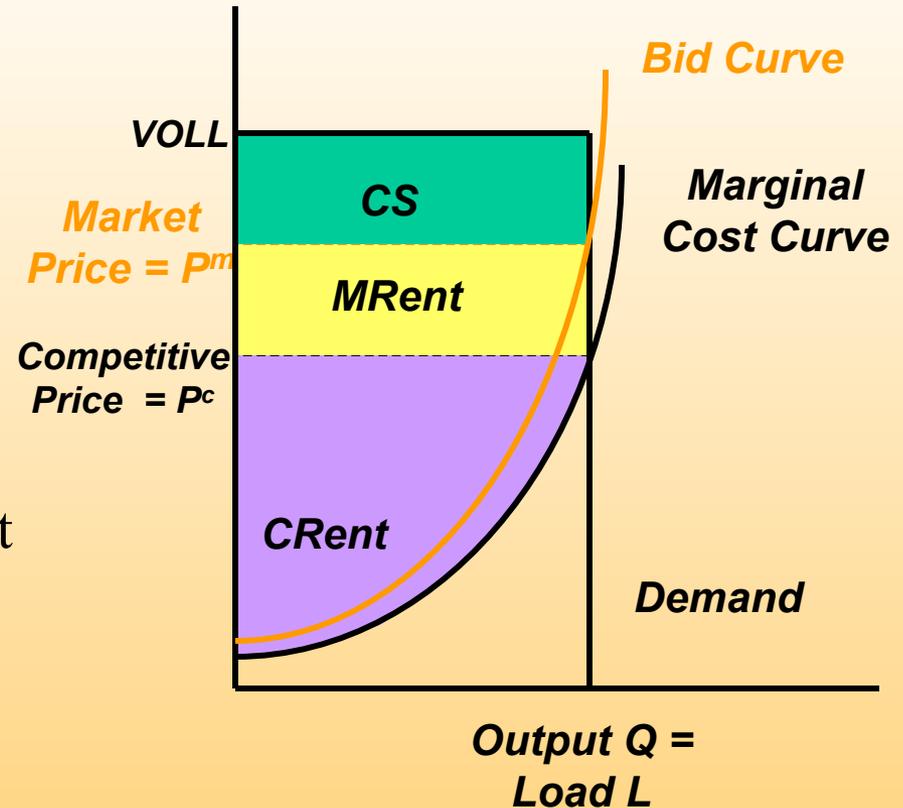
Economic Surpluses Under Market Power

- **Monopoly Rent** (MRent) is the excess profit generators capture by bidding above their marginal cost curve.

$$MRent \cong (P^m - P^c) * Load$$

- **Competitive Rent** (CRent) is what producers should receive for providing output when the market is competitive.

$$CRent = P^c * L - PC$$

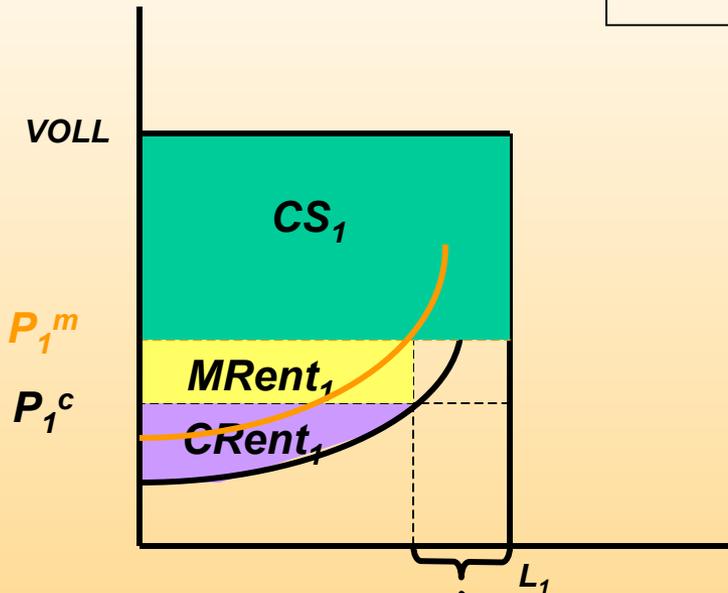


Case assumptions: market power, no congestion, & no losses

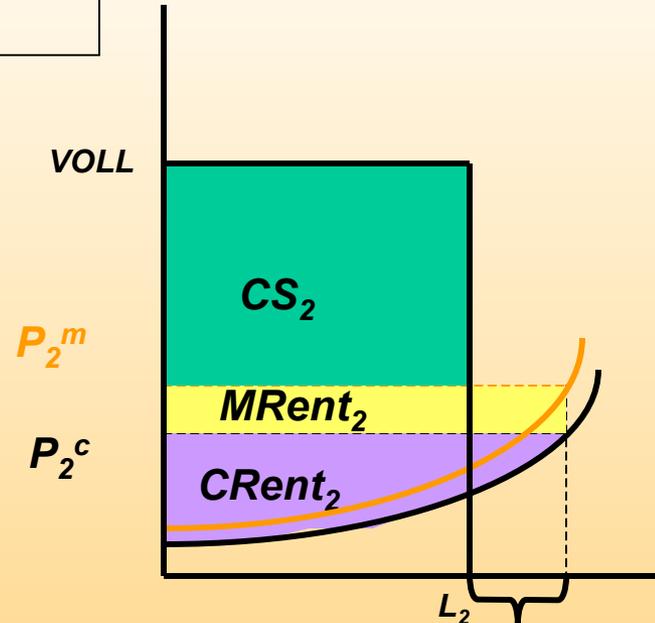


**Case assumptions:
market power,
congestion, & no
expansion**

1 = Importing Zone



2 = Exporting Zone

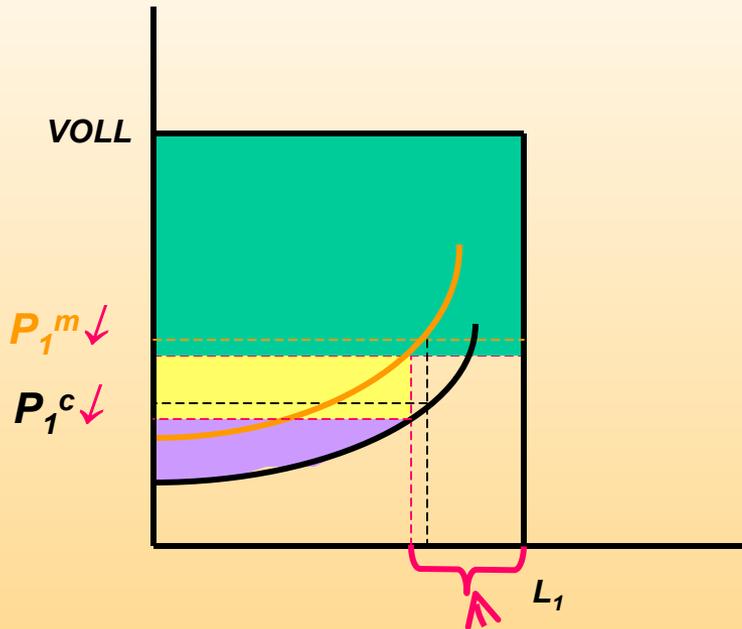


Power transferred = Line Limit T

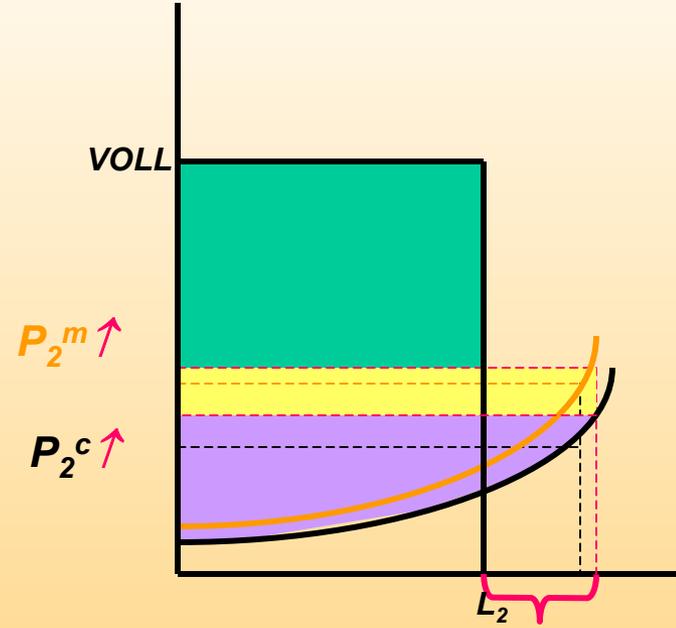


**Case assumptions:
market power,
congestion, &
expansion**

1 = Importing Zone



2 = Exporting Zone



**Power transferred =
Line Limit $T + \Delta T$**



Impact of Transmission Expansion on Monopoly Rent

- **Transmission expansion expands number of suppliers than can compete to supply energy at any location.**
- **Transmission expansion reduces strategic suppliers' ability to bid high.**
- **Transmission expansion reduces monopoly rent for strategic suppliers comparing to without expansion.**
- **Reduction of monopoly rent is good to the society and to ratepayers.**



Modified Benefit Test

- **Modified Societal Test excludes all producers' monopoly rent in surplus and benefit calculation.**
- **Modified Participant/Ratepayer Test excludes relevant producers' monopoly rent in surplus and benefit calculation.**



CAISO Proposed Transmission Evaluation Criteria (still under discussion)

| Case | Pass Societal Test? | Pass Modified Societal Test? | Pass ISO Modified Participant/Ratepayers' Test? | CAISO Recommendation |
|------|---------------------|------------------------------|---|---|
| 1 | Yes | Yes | Yes | Yes |
| 2 | Yes | Yes | No | Ask neighbors to participate in funding |
| 3 | Yes | No | Yes | Yes |
| 4 | Yes | No | No | No |
| 5 | No | Yes | Yes | Yes |
| 6 | No | Yes | No | No |
| 7 | No | No | Yes | Yes |
| 8 | No | No | No | No |



Overview of Illustrative Path 26 Study

- **Path 26 consists of three 500 kV lines between Midway and Vincent.**
- **Current rating is 3400 MW (N-S) and 3000 MW (S-N)**
- **Possible upgrade to 4400 MW (N-S) and 4000 MW (S-N) by 2008.**



Identifying Benefits in An Example Case Study

For a typical Scenario in 2013 – Path 26 Upgrade

| Perspective | Description | Consumer Benefit (\$M) | Producer Benefit (\$M) | Transmission Owner Benefit (\$M) | Total Benefit (\$M) | Production Cost Saving (\$M) |
|--------------------------|-----------------------------------|-------------------------------|-------------------------------|---|----------------------------|-------------------------------------|
| <i>Societal</i> | <i>WECC Total</i> | <i>34.38</i> | <i>(25.76)</i> | <i>(6.59)</i> | <i>2.02</i> | <i>2.02</i> |
| <i>Modified Societal</i> | <i>WECC Total</i> | <i>34.38</i> | <i>(16.92)</i> | <i>(6.59)</i> | <i>10.87</i> | |
| <i>Modified CAISO</i> | <i>CAISO Ratepayer Subtotal</i> | <i>11.05</i> | <i>(3.98)</i> | <i>(0.87)</i> | <i>6.2</i> | |
| | <i>CAISO Participant Subtotal</i> | <i>11.05</i> | <i>4.59</i> | <i>(0.87)</i> | <i>14.77</i> | |



Acronyms

- **CS**: Consumer Surplus
- **TS**: Total Surplus
- **VOLL**: Value of Lost Load
- **CRR**: Congestion Revenue Rights
- **TO**: Transmission Owner
- **Δ CS**: Consumer Benefit
- **MRent**: Producer Monopoly Rent
- **CRent**: Producer Competitive Rent
- **Δ CR**: Transmission Owner (or CRR holder) Benefit
- **Δ MRent**: Producer Monopoly Benefit
- **Δ CRent**: Producer Competitive Benefit
- **CTL**: Cost to Load
- **PS**: Producer Surplus
- **CR**: Congestion Revenue
- **PR**: Producer Revenue
- **PC**: Production Cost
- **SB**: Societal Benefit
- **Δ PS**: Producer Benefit