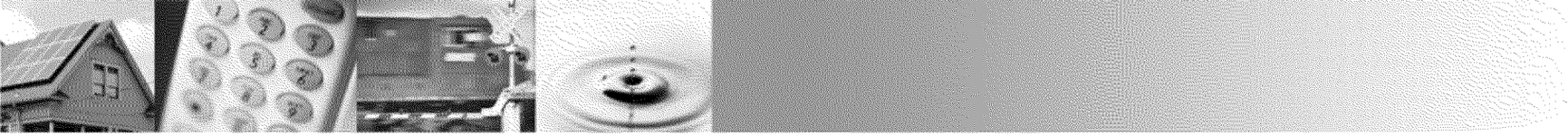


R.12-03-014: Energy Division Workshop – Operating Flexibility Modeling

Nathaniel Skinner

Senior Analyst, Generation & Transmission Planning

California Public Utilities Commission

September 19, 2012

Remote Access

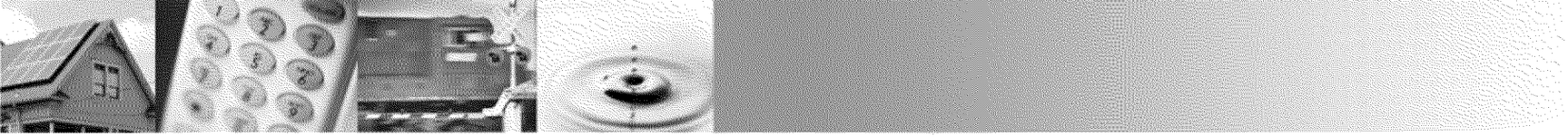
WebEx
Meeting Number: 741 769 312
Meeting Password: LTPP

https://van.webex.com/van/j.php?ED=189577152&UID=491292852&PW=NNGQ4MGM0MTBk&RT=MiM0

Call in #:
866-758-1675
*Note: *6 to mute/unmute*

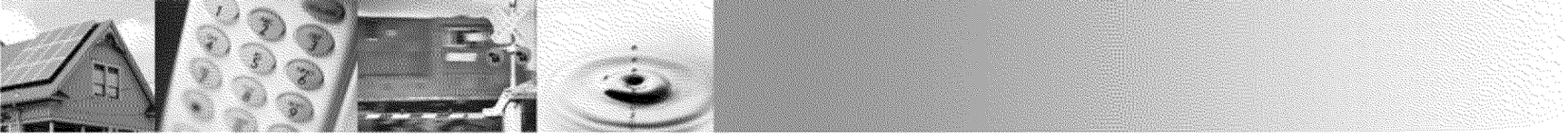
Passcode:
3481442

Upon entry to the call, please place yourself on mute, and remain on mute unless you are asking a question



Agenda

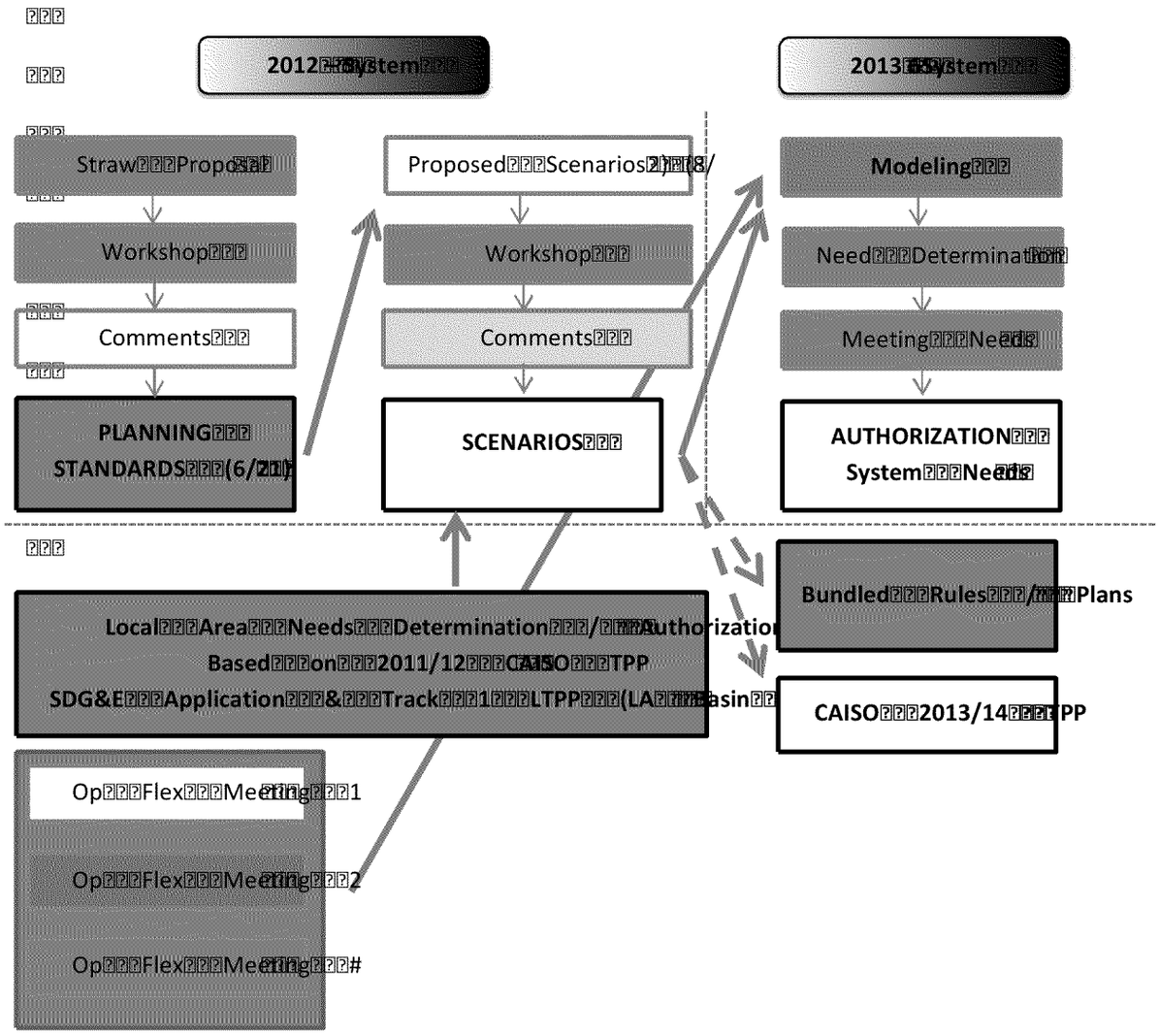
Time꿱□η	Item꿱□η
10:00 - 10:10꿱□η	Introduction꿱□η
10:10 – 10:45 꿱□η	Revisiting the “Step 0” and “Step 1” methodologies꿱□η
10:45 - 11:15꿱□η	Review of activities between 2010 LTPP settlement and today꿱□η
11:15 – 12:15꿱□η	Review probabilistic methodology for evaluating flexibility꿱□η
12:15 – 1:10꿱□η	Lunch 꿱□η
1:10 – 2:00꿱□η	Should and how can operating flexibility criteria be understood within the context of NERC/ WECC standards꿱□η
2:00 – 2:30꿱□η	Considering & modeling resources to meet operating flexibility needs꿱□η
2:30 – 2:45꿱□η	Break 꿱□η
2:45 – 3:00꿱□η	Scenarios and Assumptions and informing other processes꿱□η
3:00 – 3:15꿱□η	Thoughts on the Flexibility Procurement Modeling Challenge
3:15 – 3:45꿱□η	Q&A Session꿱□η
3:45 – 4:00꿱□η	Wrap-up / Next steps꿱□η



Workshop Purpose

- Review past (2010 LTPP) Operating Flexibility modeling approaches
- Examine proposed modeling approaches for the 2012 LTPP
- Begin framing discussion for meeting any needs identified for end of 2013 decision

Roadmap



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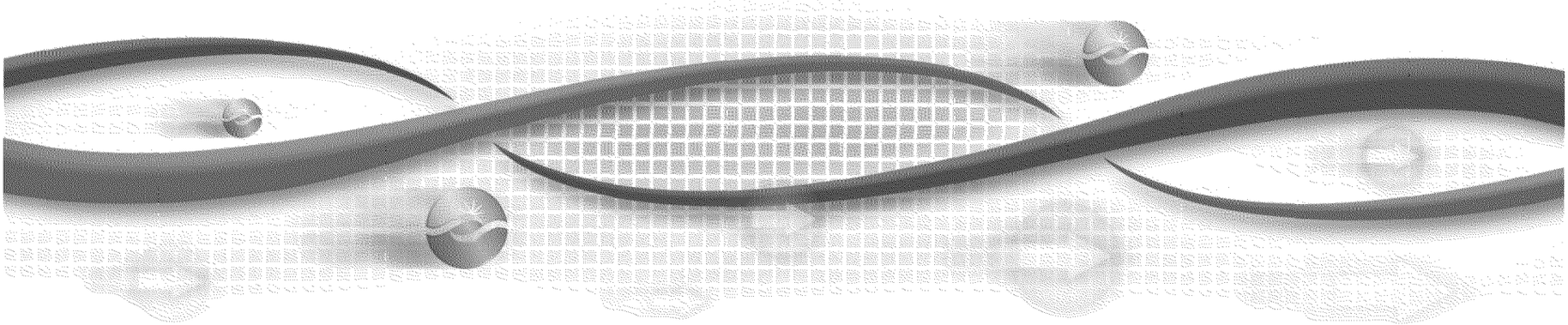

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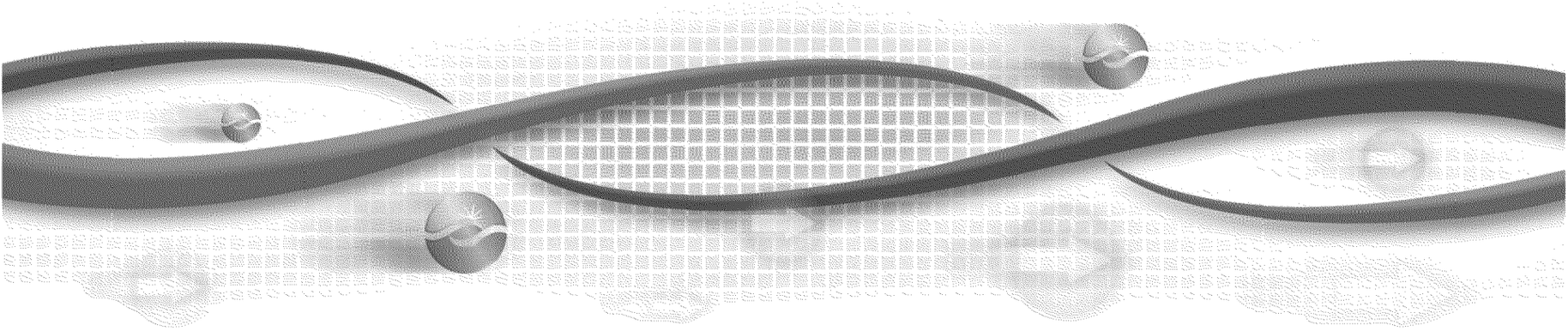

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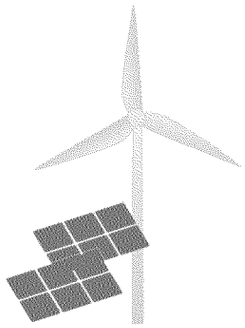

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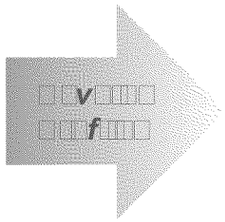

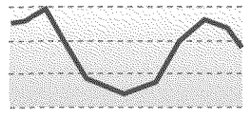

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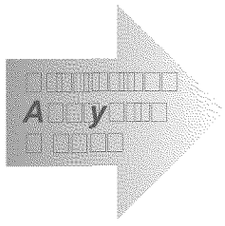

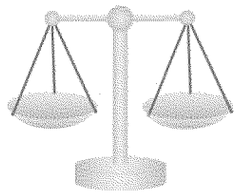

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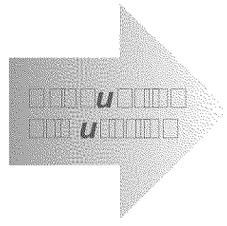

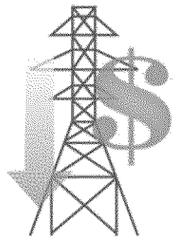

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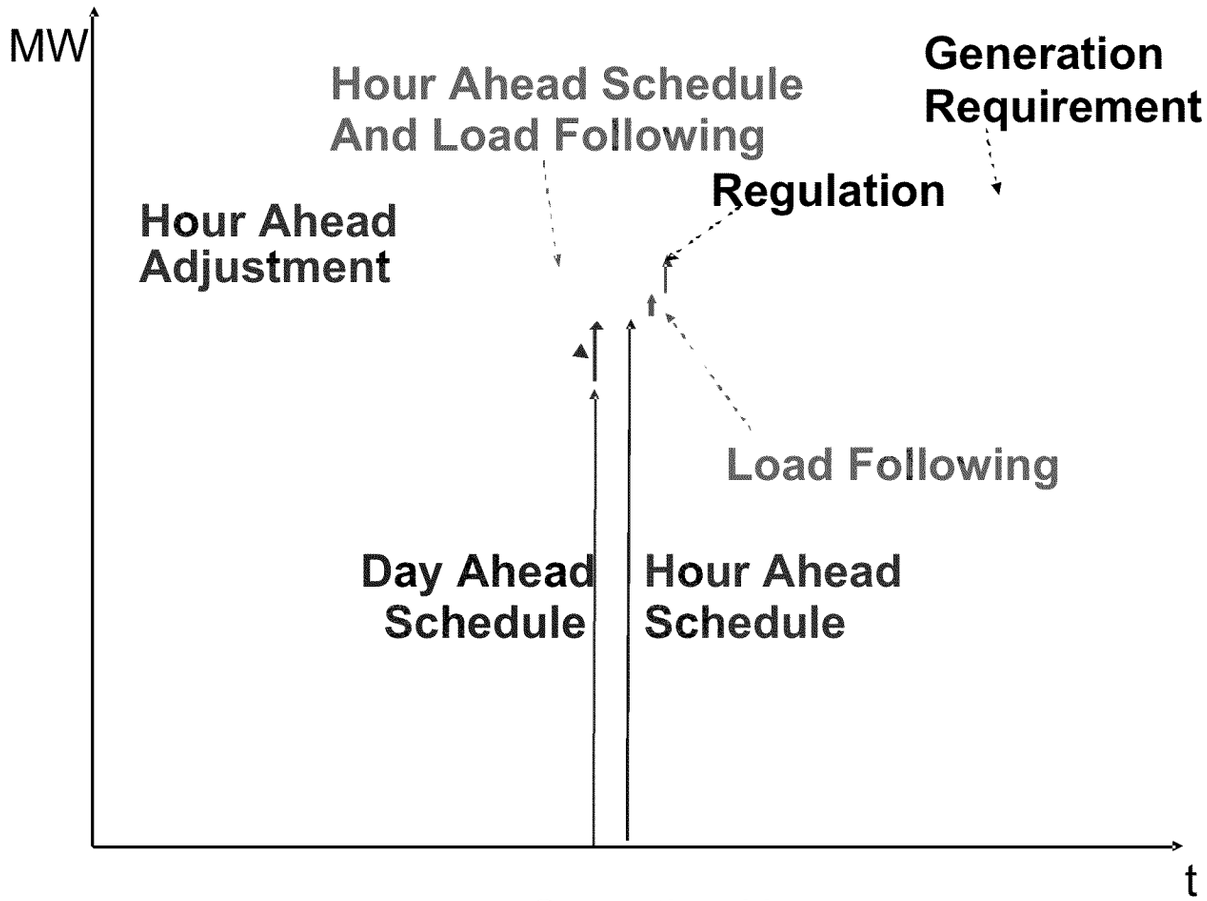
  - Forecast quality: Load, Wind and Solar forecast errors
  - Interaction between load, wind and solar: net variability
  - Market timeline: how fast the market re-commit and re-dispatch the controllable resources



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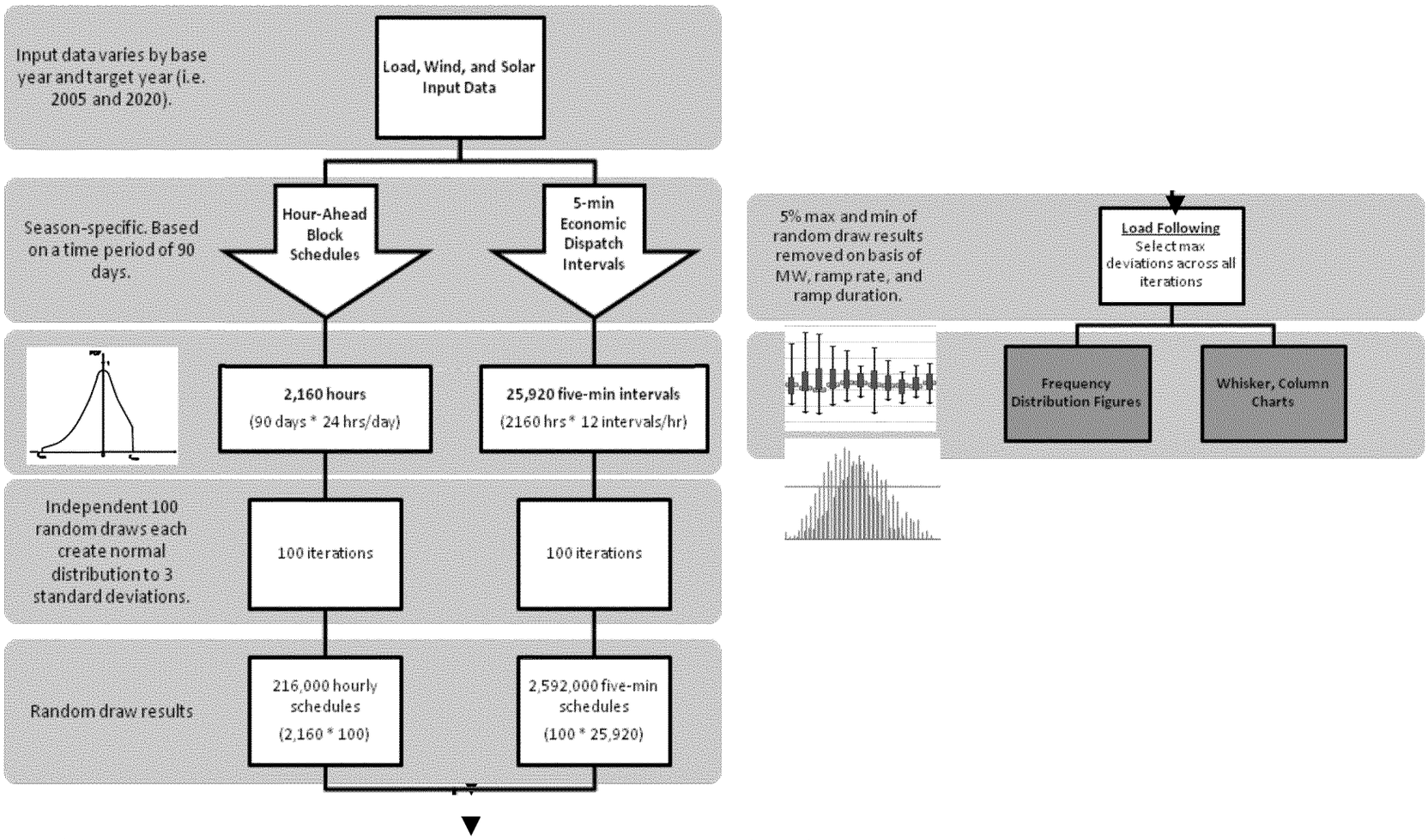
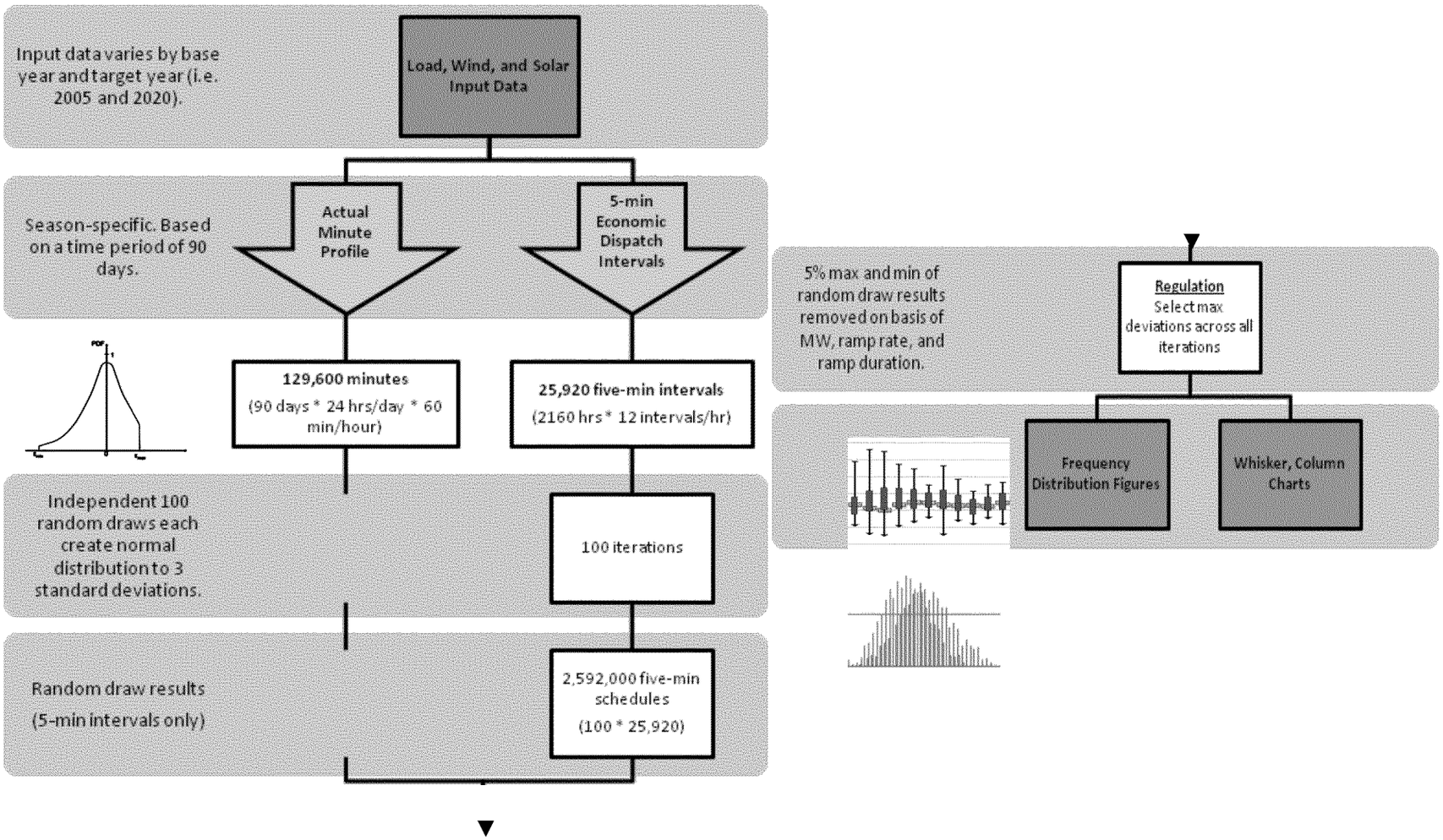

Input data varies by base year and target year (i.e. 2005 and 2020).
Load, Wind, and Solar Input Data
Season-specific. Based on a time period of 90 days.
Hour-Ahead Block Schedules
5-min Economic Dispatch Intervals
2,160 hours
(90 days * 24 hrs/day)
25,920 five-min intervals
(2160 hrs * 12 intervals/hr)
Independent 100 random draws each create normal distribution to 3 standard deviations.
100 iterations
100 iterations
Random draw results
216,000 hourly schedules
(2,160 * 100)
2,592,000 five-min schedules
(100 * 25,920)
5% max and min of random draw results removed on basis of MW, ramp rate, and ramp duration.
Load Following
Select max deviations across all iterations
Frequency Distribution Figures
Whisker, Column Charts


Input data varies by base year and target year (i.e. 2005 and 2020).
Load, Wind, and Solar Input Data
Season-specific. Based on a time period of 90 days.
Actual Minute Profile
5-min Economic Dispatch Intervals
129,600 minutes
(90 days * 24 hrs/day * 60 min/hour)
25,920 five-min intervals
(2160 hrs * 12 intervals/hr)
Independent 100 random draws each create normal distribution to 3 standard deviations.
100 iterations
Random draw results
(5-min intervals only)
2,592,000 five-min schedules
(100 * 25,920)
5% max and min of random draw results removed on basis of MW, ramp rate, and ramp duration.
Regulation
Select max deviations across all iterations
Frequency Distribution Figures
Whisker, Column Charts

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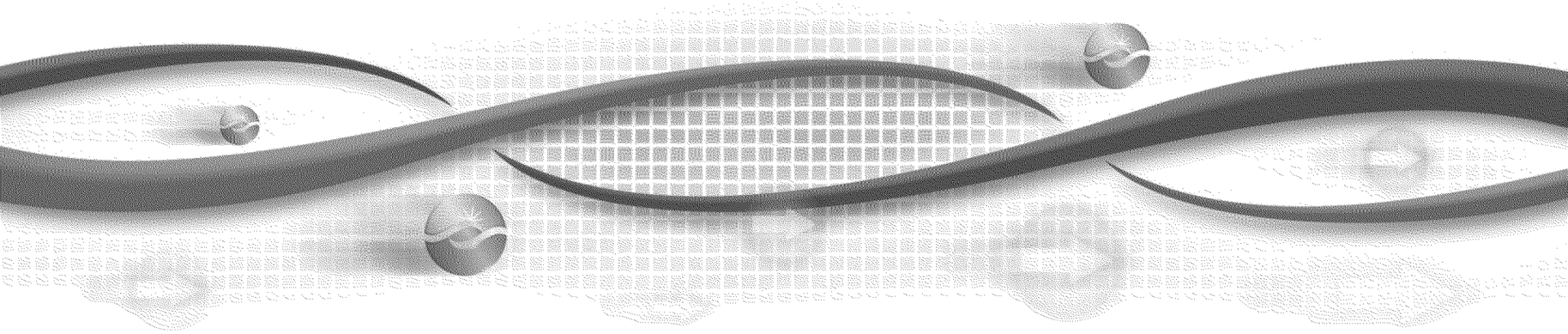

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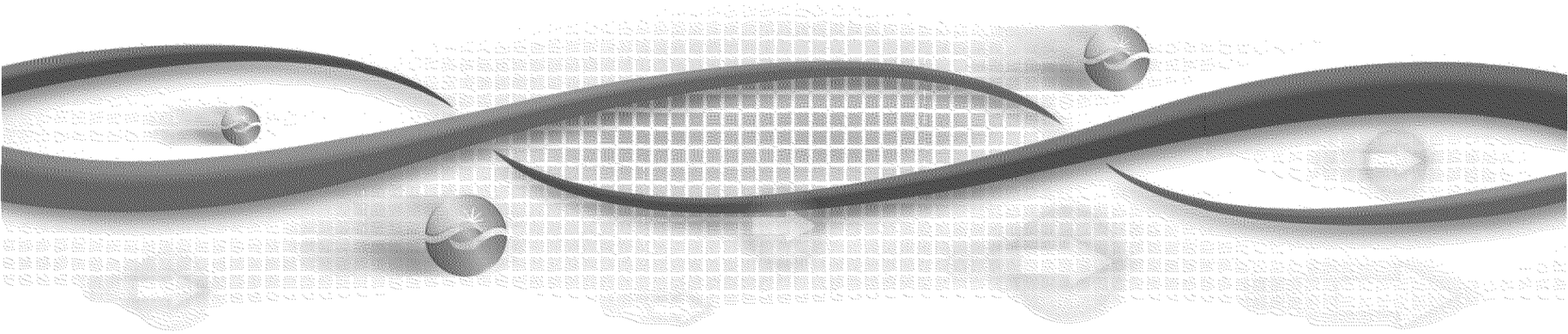

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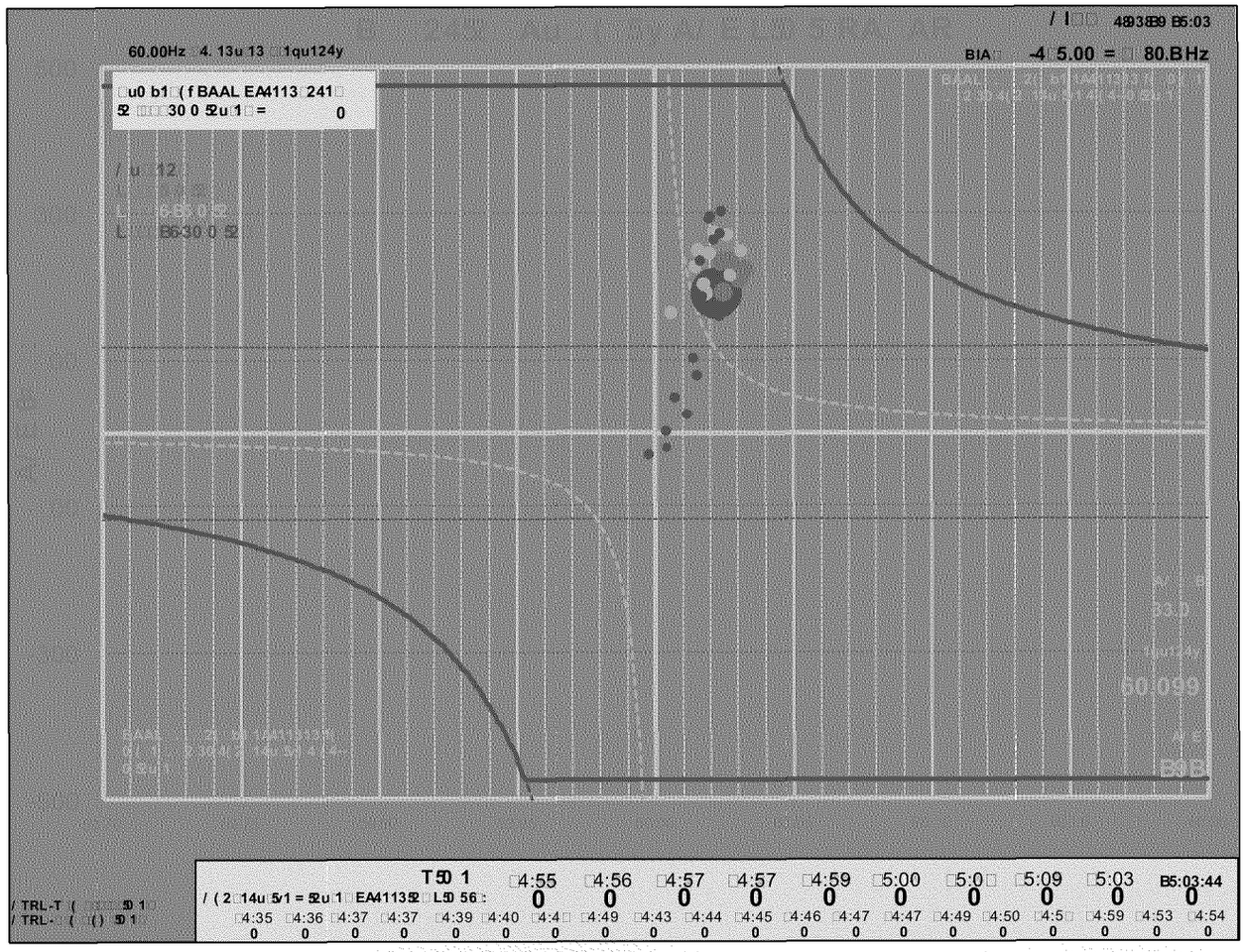
- BAAL is designed to replace CPS2
- BAAL relaxes area regulation needs
- ACE is allowed to be outside BAAL for up to 30 minutes



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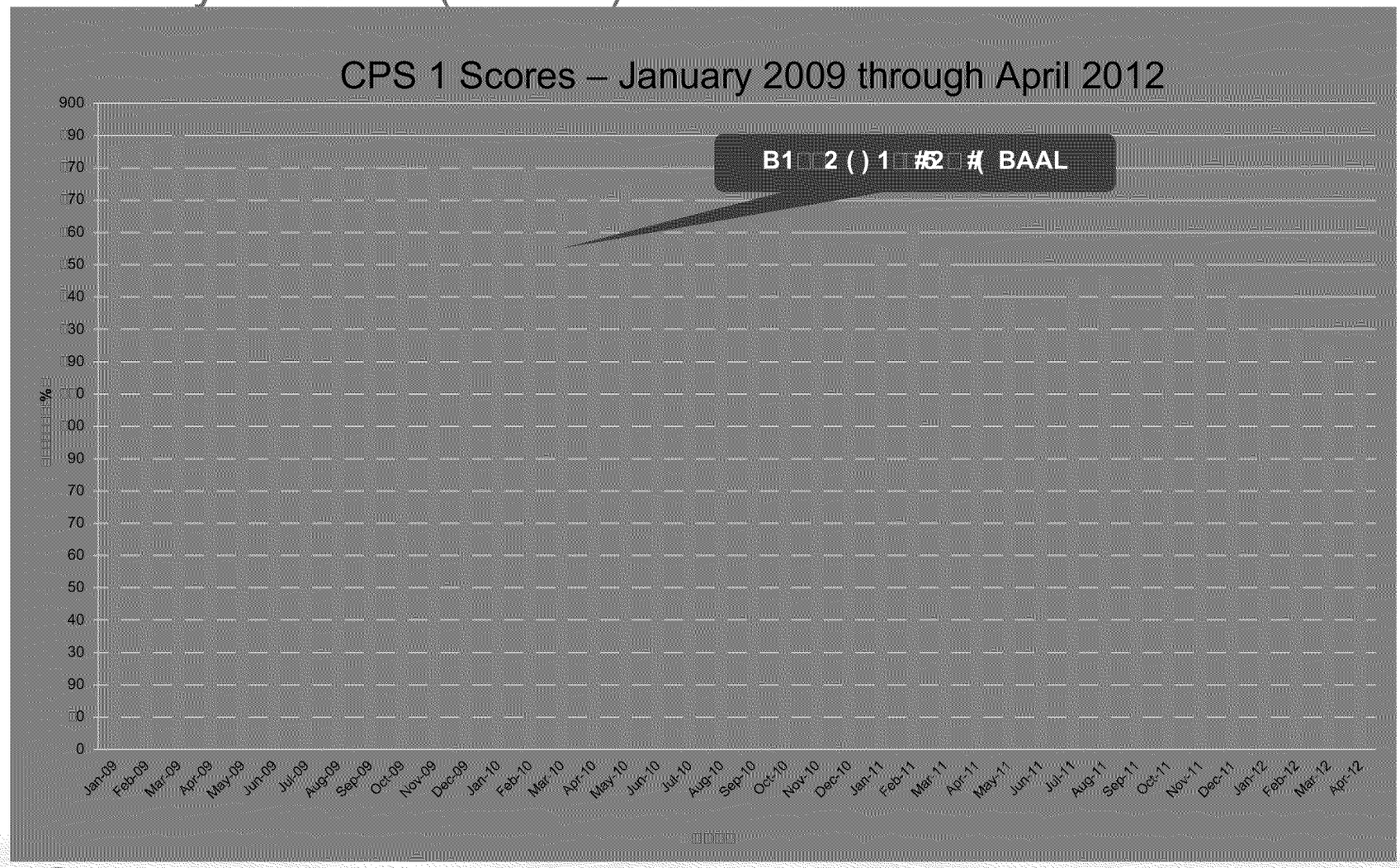

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- **Control Performance Standard (CPS1)** - measures the control performance of a BA's by comparing how well its ACE performs in conjunction with the frequency error of the Interconnection

- **Balancing authority Ace Limit (BAAL)** - is a real-time measure of Area Control Area and system frequency which cannot exceed predefined limits for more than 30-minutes

- **Disturbance Control Standard (DCS)** - is the responsibility of the BA following a disturbance to recover its ACE to zero if its ACE just prior to the disturbance was greater than zero or to its pre-disturbance level if ACE was less than zero - within 15 minutes

- **Control Performance Rating**

  Pass is when CPS1 ≥ 100%; $BAAL_{L5\,0\,5\square}$ ≤ 30 minutes & DCS = 100%

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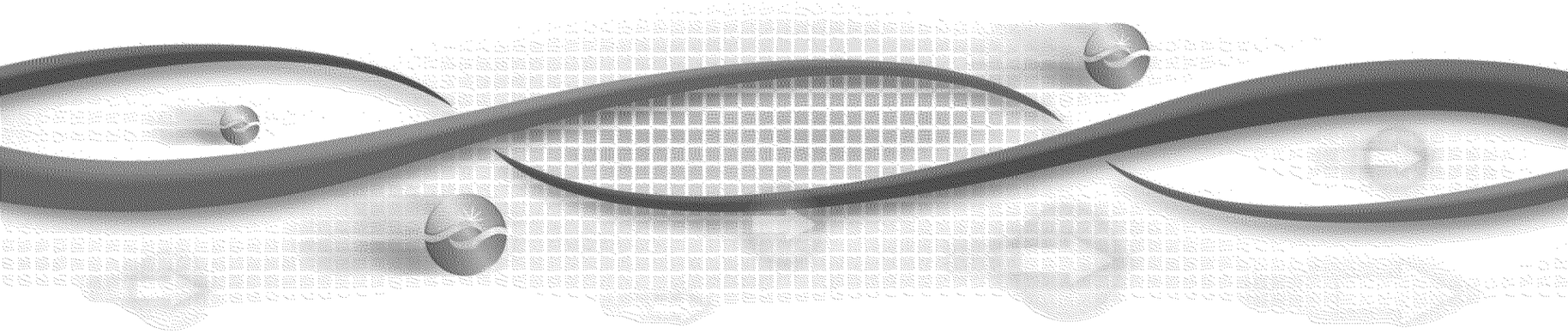

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- =(21 / %+(*50 u+%5(2 311 0 521* 52*uff3451 2 %0)52 4%) %45y) (b%b55y
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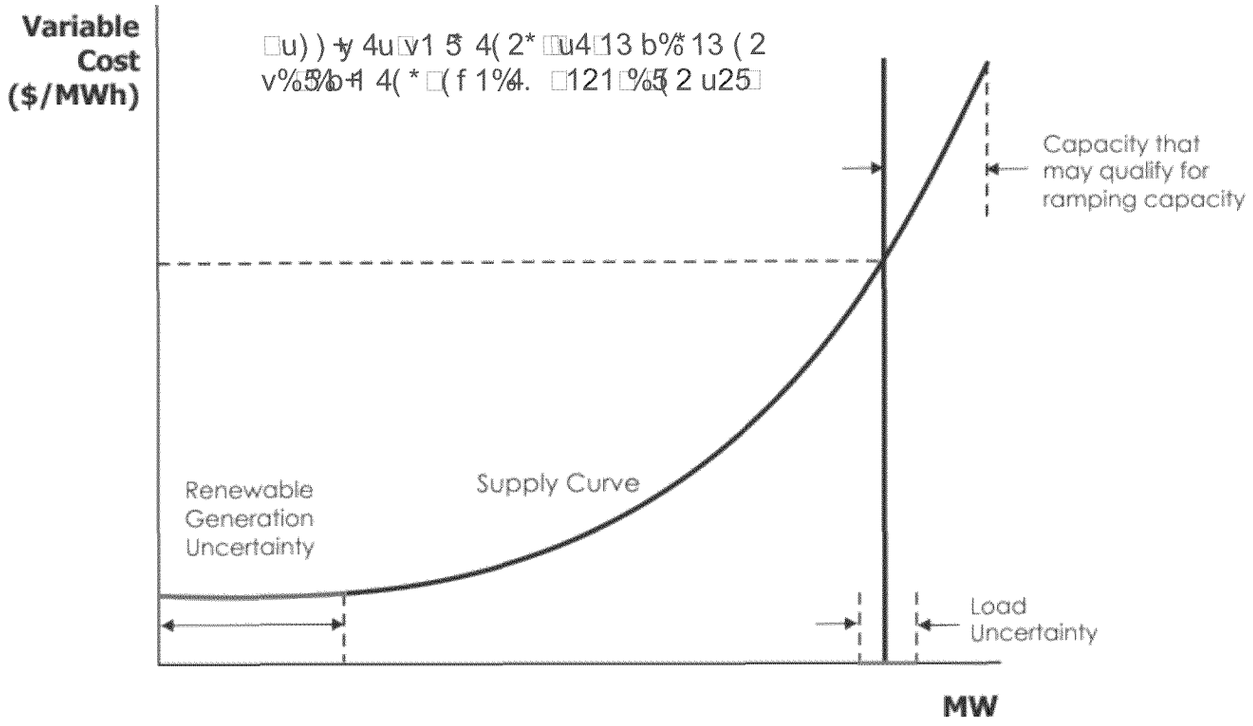

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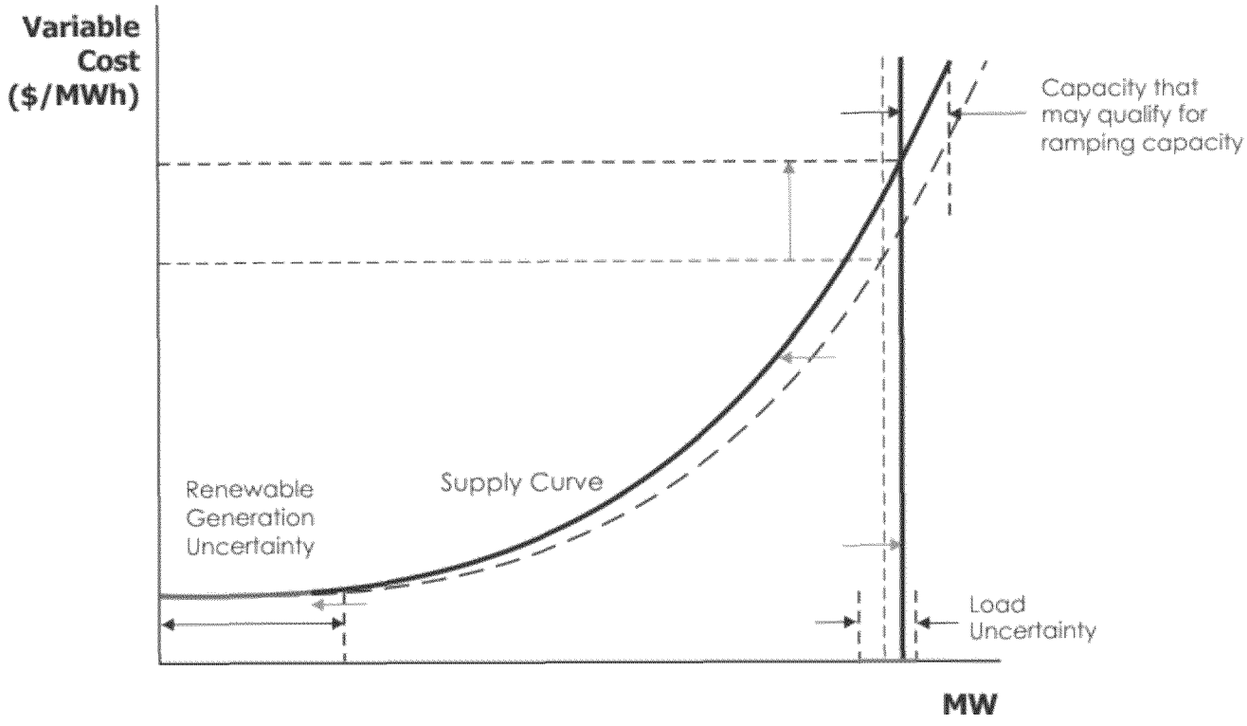

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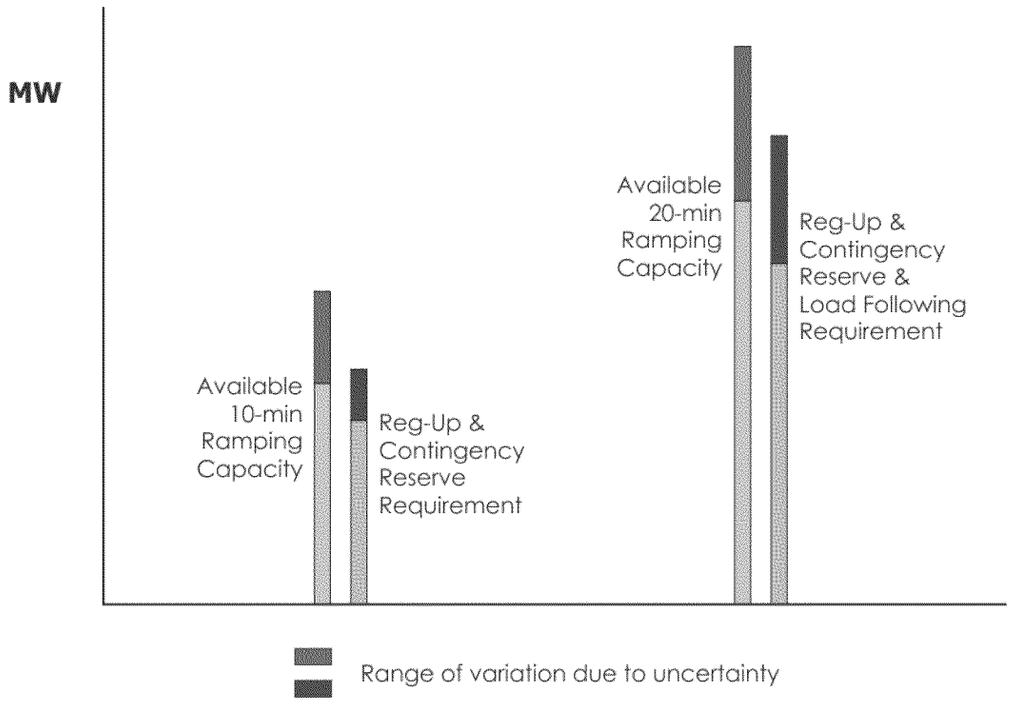
MW
Available 10-min Ramping Capacity
Reg-Up & Contingency Reserve Requirement
Available 20-min Ramping Capacity
Reg-Up & Contingency Reserve & Load Following Requirement
Range of variation due to uncertainty

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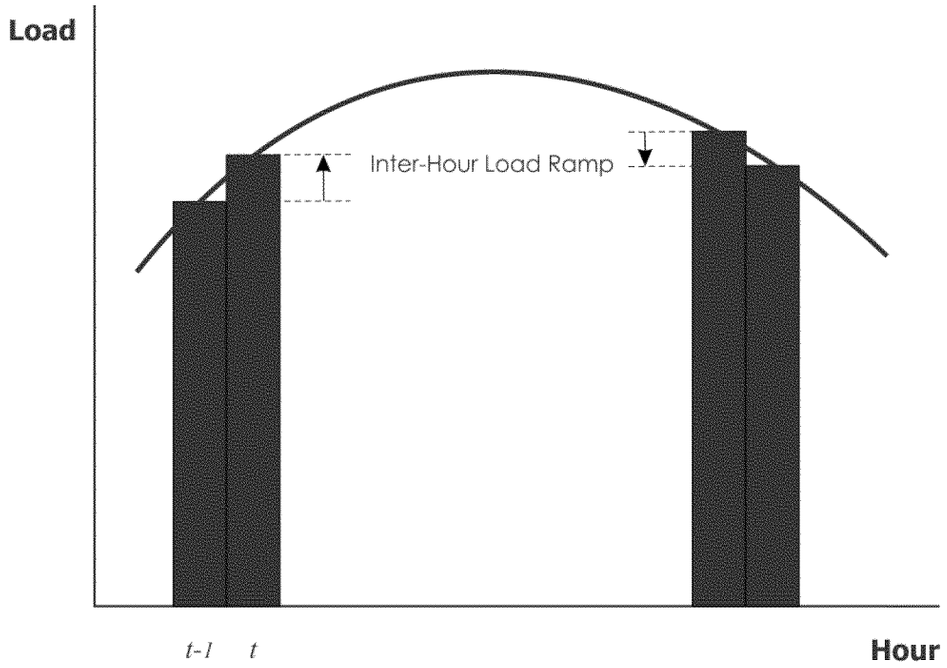
- U255(0 35* 5u5(2 fu245(2* b%*13 (2 f(413 %23 0 %52 12%241 (u%1 %1* (f 1%4. 121%5(2 u25

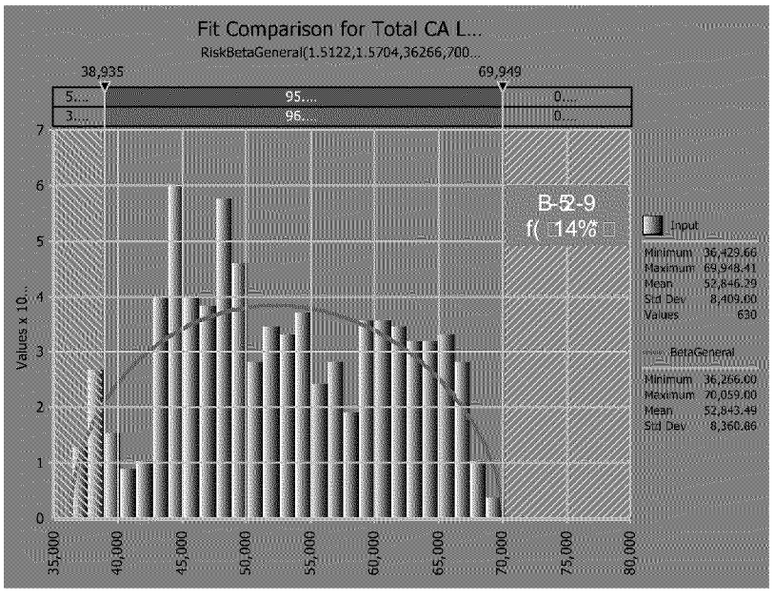
l2 1 -. (u + (%3 %0) 5 * 4%#4u+%13 b%*13 (2 . (u + y + (%3 f(14%* .



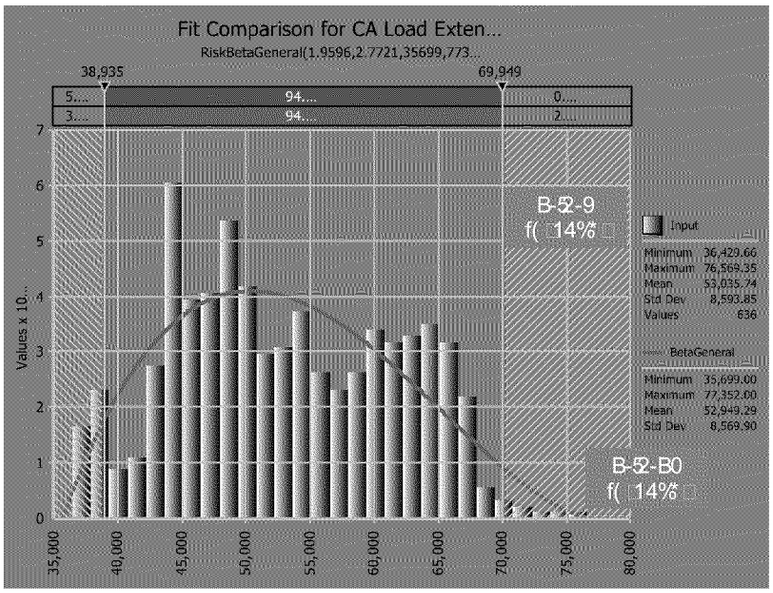
- Upward direction only
- A new stochastic variable
- Met by 60-min ramping capability
- A part of load

$$Inter\text{-}HourRamp_t = \max(0, Load_t - Load_{t-1})$$

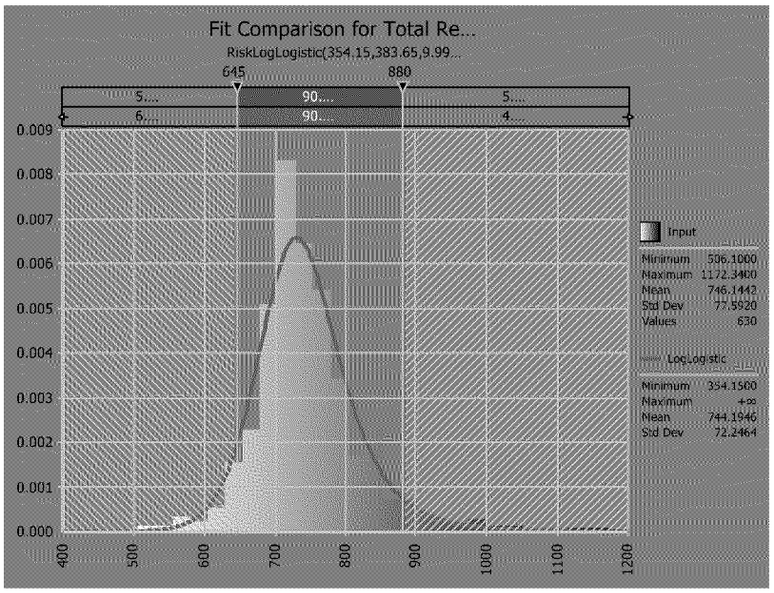
T. 1* 1 %1 1A%0) +1* (f) (b%b55y 35 5bu5 2
fu24 5 2* (f * (4. % 54 v%5%o+1* .

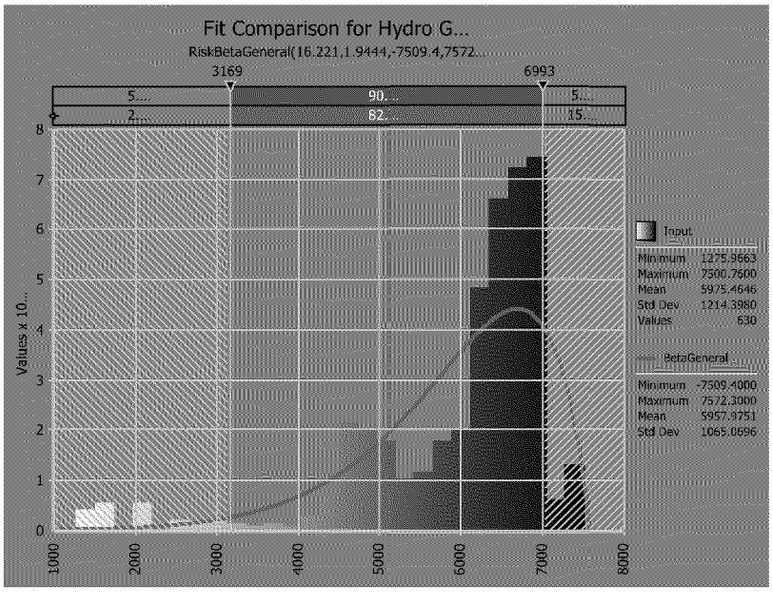


EA) +(52 . 1) (b%b55y (. %v1
+(%3 . 5 . 1 . %2 B-52-9 f(14%

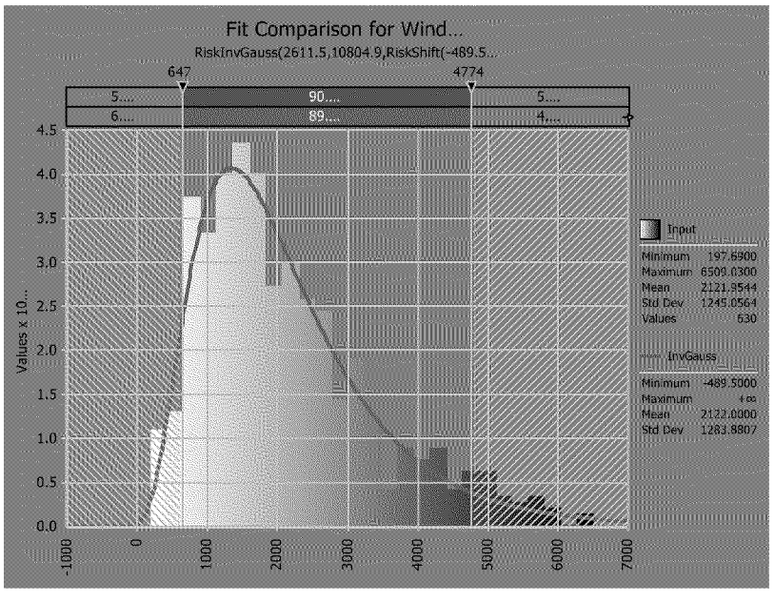


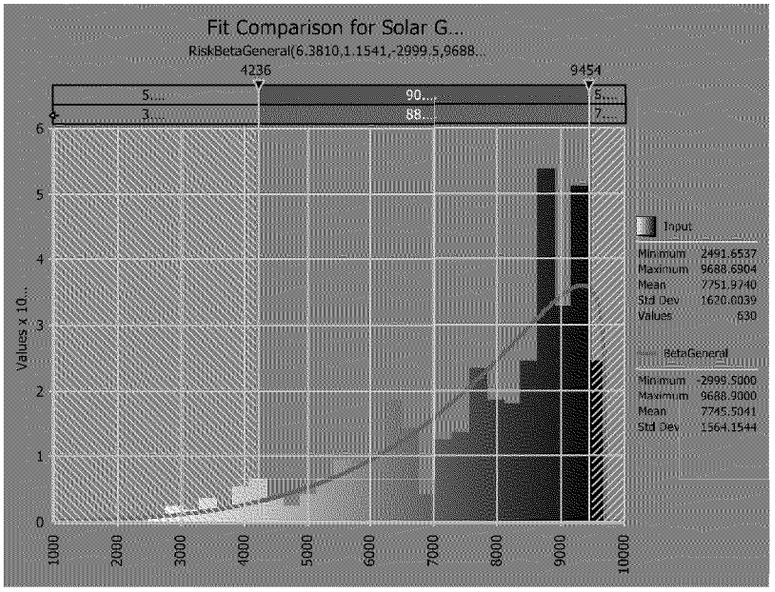
EA%0)+1* (f) (b%o55y 35* 5ou 5(2 fu24 5(2* (f
* ((4. %* 54 v%o5%o+1* . 64(2.:





EA%0)+1* (f) (b%o55y 35* 5ou 5(2 fu24 5(2* (f
* ((4. %* 54 v%o5%o+1* . 64(2 .:





/ (□1+%5(2* %0 (2□ .1 * (4. %* 54 v%5%b+1* %1 12f(413.

	L(□3	L(□3 R□0)	, 523 G12	□(+□□ G12	Hy3□(G12	R1□U	L□U
L(□3	B	0.9774	-0.0947	-0.B997	0.4309	0.370B	0.0799
L(□3 R□0)	0.9774	B	-0.3779	0.6B56	0.0779	0.9064	-0.3B93
, 523	-0.0947	-0.3779	B	-0.B6B7	0.9755	-0.0B07	0.0609
□(+□□	-0.B997	0.6B56	-0.B6B7	B	0.0954	-0.BB0B	-0.5064
Hy3□(	0.4309	0.0779	0.9755	0.0954	B	0.3094	-0.B973
R1□U	0.370B	0.9064	-0.0B07	-0.BB0B	0.3094	B	0.B4B5
L□U	0.0799	-0.3B93	0.0609	-0.5064	-0.B973	0.B4B5	B

T. 5 5 %2 1A%0) +1 (f □.1 4(□1+%5(2 0 %□5A

G121 %5(2 u25* 52 .1 *(4. %* 54 0 (31+. %v1 .1 f(+(&52 4. %%41 5 54* f(0 .1 ' +1A(* 0 (31+

- (0 52) u 3%%
  - = %A50 u0 %23 0 525 0 u0 4%) %45y
  - R%0) %1
  - (413 (u%1 %23 0 %52 12%241 (u%1 %1*
- (0 *50 u+%5(2 1*u+*
  - Av1 %1 121 %5(2 4(* 6(31 1 0 521 %2 5255%+35*) %4. (31:

G121 %5(2 u25 %v%5%b55y 5* *(4. %* 54%+y 31 1 0 5213 52 1%4. 51 %5(2 (f . 1 = (21 / %+(*5 u+%5(2*.

- (413 %23 0 %52 12%241 (u% 1* %1 31 1 0 5213 5231) 12312+y f(1%4. 121 %5(2 u25

- E%4. (f . 1 (u% 1* 5* 31 1 0 5213 b%*13 (2 . 1 u25'* (u% 1 %1 %23 %3 %& u* 52 %u25(0 35* 5u5(2 fu24 5(2

- A 0 %52 12%241 (u% 1 %+(4%5(2 f%4(5* u* 13 (1) 1* 12 * 1%(2%+) %1 2 (f 0 %52 12%241 *4. 13u+1*

- A u25 5* u2%v%5%b+1 &. 12 %2y (21 (f . 1 (u% 1* (44u *

/ (2 □5u 5(2* (f % □121 □%5(2 u25 □(121 □y %23 □%0) 52 □ 4%) %45y %1 * ubj14 □(:

- B0-0 52 u) &%3 □%0) 52 □ 4%) %45y 4(2* □%52 □

$$AS_i \le 0 \quad \square\square\square 0 \times RampRate_i, MaxCap_i - MinCap_i \square$$

- 90-0 52 u) &%3 □%0) 52 □ 4%) %45y 4(2* □%52 □

$$AS_i + LFU_i \le \min(20 \times RampRate_i, MaxCap_i - MinCap_i)$$

- 60-0 52 u) &%3 □%0) 52 □ 4%) %45y 4(2* □%52 □

$$AS_i + LFU_i + LdRamp_i \le \min(60 \times RampRate_i, MaxCap_i - MinCap_i)$$

- = %A5 0 u0 4%) %45y 4(2* □%52 □

$$E_i + AS_i + LFU_i + LdRamp_i \le MaxCap_i$$

$E_{\square}$ – energydispatch	$A\square_{\square}$ – totalupward ancillaryservice contribution
$L\square U_{\square}$ – load followingup contribution	$L\square R\square\square_{\square}$ – inter-hour load ramp

T(%+4(2 5u 5(2* by %+ 121 %5(2 u25* *. (u-3 0 11 121 y %23 %0) 52 4%) %45y 1qu510 12*.

- B0-0 52 u) &%3 %245+%y *1 v541 1qu510 12

$$\sum_i AS_i \geq Req_{AS}$$

- 90-0 52 u) &%3 %0) 52 4%) %45y 1qu510 12

$$\sum_i \left(AS_i + LFU_i \right) \geq Req_{AS} + Req_{LFU}$$

- 60-0 52 u) &%3 %0) 52

$$\sum_i \left(AS_i + LFU_i + LdRamp_i \right) \geq Req_{AS} + Req_{LFU} + Req_{Load\ Ramp}$$

- E21 y b%%241

$$\sum_i \left(E_i + LdRamp_i \right) = Load$$

Req_{AS} – upward ASrequirement	Req_{LFU} – load following-up requirement
$Req_{Load\ Ramp}$ – inter-hour load ramp	$Load$ – total load

T. 1 0 (31+* 11- * %+1 % -4(* *(+u 5 2 (0 11 121 y %23 %+ %0) 52 4%) %45y 1qu510 12 *.

- G121 %5(2 u25* %1 35*) %4. 13 14(2(0 54%+y (0 11 +(%3 f5*

- R10 %252 qu%55 13 %0) 52 4%) %45y 5* u* 13 (0 11 u) &%3 %245+%y * 1 v541, +(%3 f(+(&52 , %23 521 -. (u +(%3 %0) 1qu510 12 *

- E21 y 35*) %4. %23 %0) 52 4%) %45y 4(2 5u5(2* %1 4(-( ) 50 5z13 &. 12 . 1 1 5* 52* uff5451 2 %0) 52 4%) %45y 5255%+y

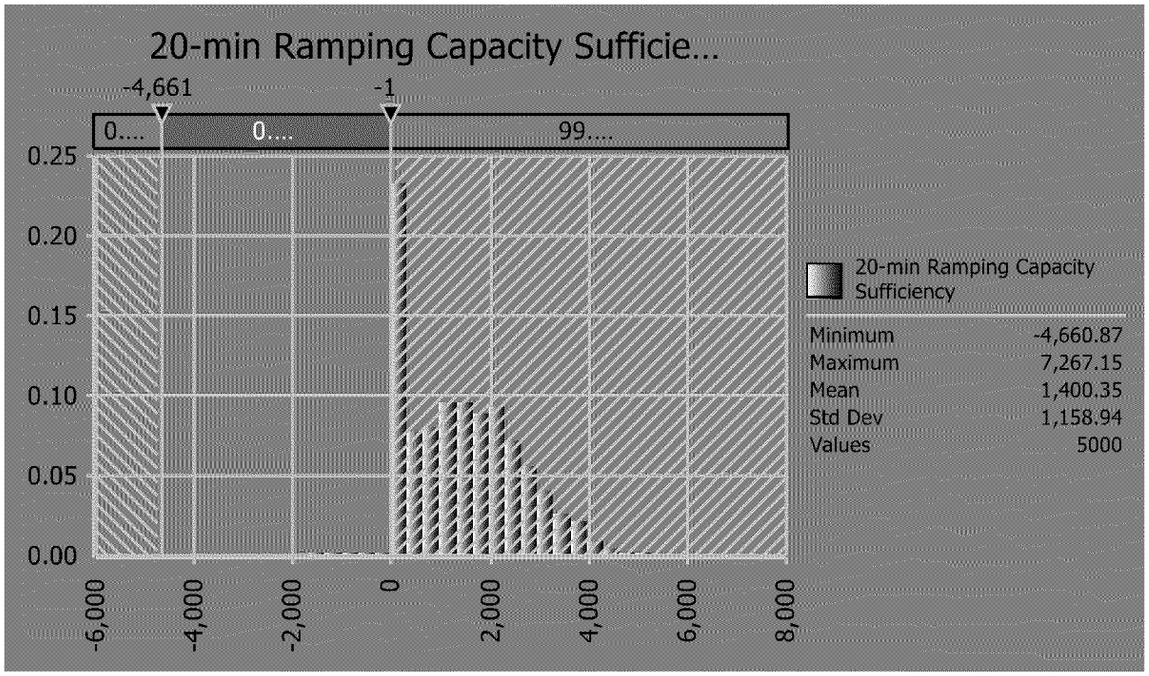
= (2 1 / % + (* 5 0 u + % 5 (2 31 1 0 5 2 1 * 5 2 * uff 3 4 5 1 2 % 0) 5 2
4 %) % 4 5 y) (b % b 5 5 y.

- = (2 1 / % + (* 5 0 u + % 5 (2 5 * 4 (23 u 4 1 3 u * 5 2 . 5 *
  * (4. % * 5 4 0 (31 +

- I 2 * uff 3 4 5 1 2 % 0) 5 2 4 %) % 4 5 y 1 * u + * % 1) 1 * 12 1 3 5 2 %
) (b % b 5 5 y 3 5 * 5 b u 5 (2 f (0 %

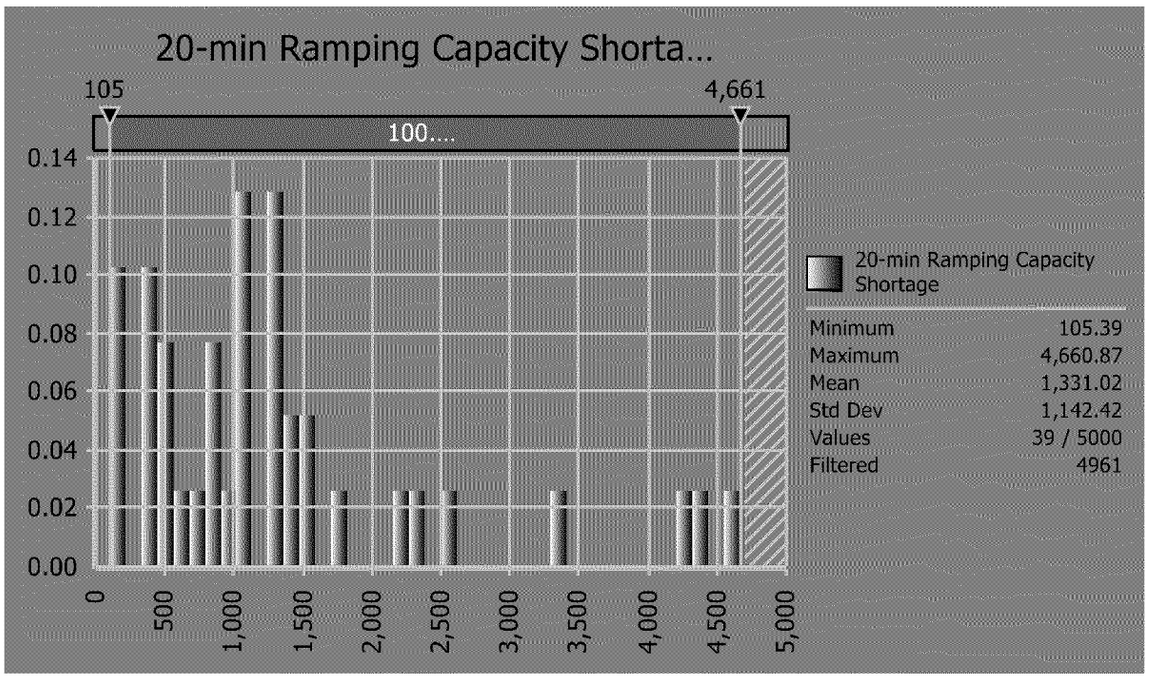
- T. 1 - 1 y 1 * u + * % 1 . 1) (b % b 5 5 y (. % v 1 % 0) 5 2
  4 %) % 4 5 y * . (% 1 1 % 4. . (u % 2 3 . 1) (b % b 5 5 y
  3 5 * 5 b u 5 (2 (f . 1 v (+ u 0 1 (f . 1 * . (% 1 *

T. 5* 1A%0) +1 . %* %0.7%) □(b%o55y □(. %v1 90-0 52
□%0) 52□ 4%) %45y * . (□□%□1 1%4. . (u□.



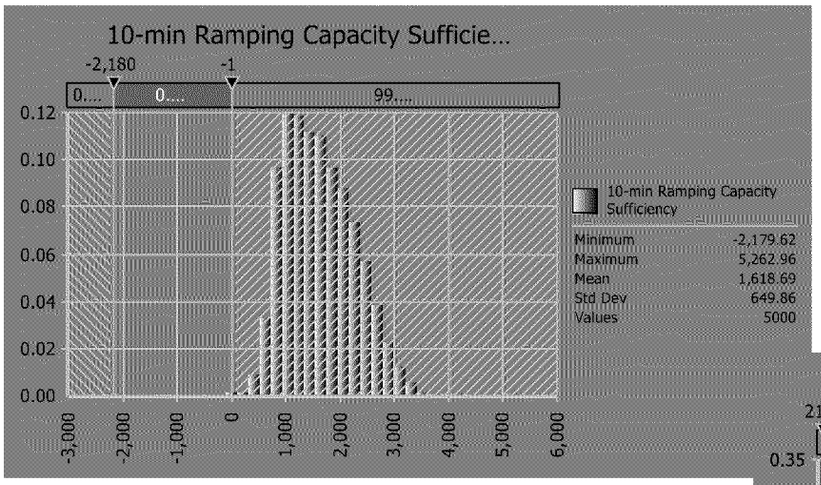
R1*u+* f(□.1 □u) 1 -' 1%) 1 5(3.

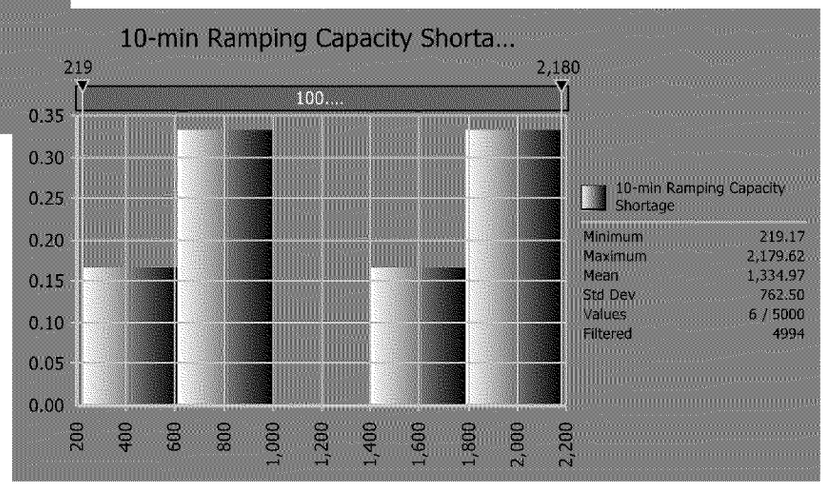
T. 1 . 5 . 1* 90-0 2 %0) 2 4% %45y * . (%1 5 4,66B
= , 2 . 5 1A%0) +1 .



R1*u+* f(.1 u) 1 -' 1%) 1 5 3.

T. 1) (b%o55y (. %v1 B0-0 52 %0) 52 4%) %45y
. (%1 1%4. . (u 5 0.B%.





R1*u+* f(.1 u) 1 -' 1%) 1 5(3.

= (2 1 / % + (* 5 0 u + % 5 2 1 * u + * f (% +) 1 5 3 * % 1
* u 0 0 % 5 z 1 3 % * f (+ (& * :

	Example 꿱□ηCase			
	Super-・ Peak		Summer 꿱□ηOff-・ Pea	
	10-・ min	20-・ min	10-・ min	20-・ min
#꿱□ηof 꿱□ηHours 꿱□ηin 꿱□ηthe 꿱□ηPeriod	530	530	2298	2298
Probability 꿱□ηof 꿱□ηShortage	0.13%	0.78%	0.04%	0.16%
Max 꿱□ηShortage 꿱□η(MW)	2,180	4,661	1,420	3,855

/ u0 u+%5v1) (b%b555l* (f %0) 52 4%) %45y *. (%1
%1 4%4u+%13 u* 52 B52(0 5%+35* 5u 5(2.

	Example 켐□ηCase	
i	10-· min	20-· min
1	81.3%	100.0%
2	49.9%	99.8%
3	23.6%	99.1%
4	8.9%	97.2%
5	2.8%	93.0%
6	0.7%	85.8%
7	0.2%	75.4%
8	0.0%	62.7%
9	0.0%	49.0%
10	0.0%	35.9%
11	0.0%	24.6%
12	0.0%	15.9%
13	0.0%	9.6%
14	0.0%	5.5%
15	0.0%	2.9%
16	0.0%	1.5%
17	0.0%	0.7%
18	0.0%	0.3%
19	0.0%	0.1%
20	0.0%	0.1%
21	0.0%	0.0%
22	0.0%	0.0%

l 5* .1) (b%b56y (. %v1 %
+1%* *i* . (u* &5. %0) 52
4%) %45y * . (%1 52 y1% 9090.

EA) 14□13 2u0 b1□(f . (u□* &5. □%0) 52□ 4%) %45y
*. (□%□1 52 9090 %1 4%4u+%13 b%*13 (2 .1
) □(b%b5551 *.

Example꿰□η Case	
10-· min	20-· min
1.68	8.59

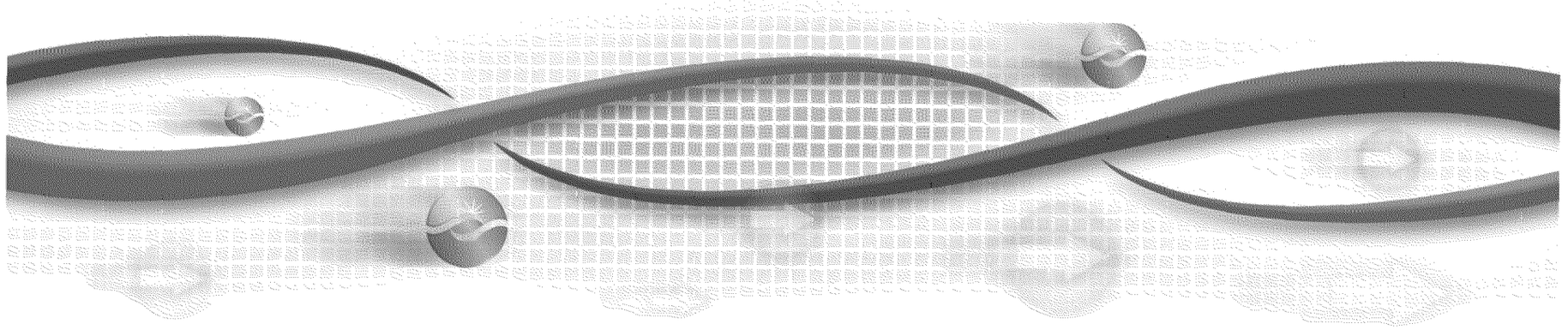
I□5 52* uff5451 2□%0) 52□ 4%) %45y 1A) 14□%5(2.

, . %□&1 +1%213 f□(0 □.5* %)) □(%4. :

- l□3(1*
  - U*1) □(b%o55y 35* □5u□5(2* □(4%) □u□1 u241□%52□51* 52 - 1y 52) u□ f%4+□(□*
  - l0) +10 12□□%0) 52□ 4(2* □%52□* %23 f+1A5o55y □1qu510 12□*
  - ' □1*12□52*uff345 12□□%0) 52□ 4%) %45y 1v12□* 52) □(b%o55* □34 f(□0 %□
- l□3(1* 2(□
  - □1453 1 u25□4(0 0 50 12□
  - l0) (*1 4. □(2(+(□54%o+4(2* □%52□*
- l□4%2 b1 50) □(v13 □(
  - U*1 0 u+5y1%□*y24. □(25z13 . 5* □(□54%o+3%%□(4%) □u□1 0 (□1 v%□5%□5(2* (f 52) u□* □(4. %* □54 v%□5%o+1*

California ISO
Shaping a Renewed Future

A □u3y (□u))(□= 11□2□
A**10 b+y B5+6AB: B3B7



' +1A(* *5 0 u+%5 2* %1 4(23u4 13 %(u) 1 f(0 %241
(f +(4%+4%) %45y 1qu5 10 12 1*(u 41* 52 9090.

- B%*1 0 (31+ H5 . -L(%3 *412%5 52 90BB LT' ' * u3y
  - R13u413 0 52 u2 50 1 (f *(0 1 310 %23 1*) (2*1 1*(u 41* f(0 4 (B . (u
- L/ R 1*(u 41*
  - A3313 3,B73 = , +(4%+4%) %45y 1qu5 10 12 6L/ R: 1*(u 41*
- A *12* 55v5y 4%*1
  - R13u413 4%) %45y (f 1v12 -b%* 13 310 %23 1*) (2*1 1*(u 41*

L/ R □1*(u□41* %1 %3313 □(□/ E %23 □□G&E z(21*.

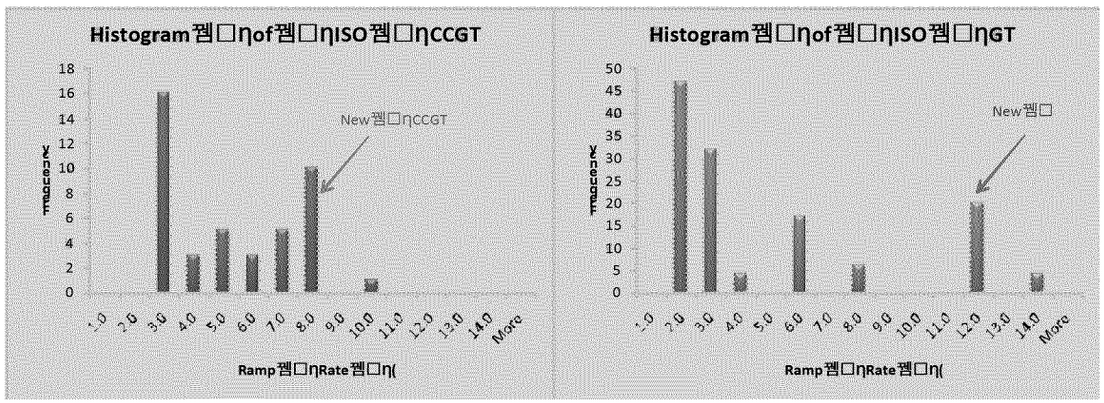
- 3,B73 = , L/ R □1*(u□41* b%*13 (2 .1 l□? ? T/ * u3y
  - L(* A2□1+1* B%*52: 9,370= ,
  - B5□ / □11- V12□u□%%1%*: 430= ,
  - □%2 □51□(: 373= , *
- L/ R □1*(u□41* %3313 %* %4(0 b52%5(2 (f / / GT %23 GT u25*
  - □/ E: 9 A500 = , / / GT u25*
  - □/ E: B7 AB00 = , L= □B00 GT u25*
  - □□G&E: B A373 = , / / GT u25□

* l□%* u0 1* .%□%2 □51□( ) □( ) (* 13 □121 □%5(2 5 524+u313 %+1%3y. □(.1 □(%+2113 52 □%2 □51□(*. (u-6 b1 373 = ,) +u*
' 5(' 54(= 300= , Qu%5+B□u*. = B00= , E*4(2353(E21□y / 12□1□= 45 = ,

L/ R □1*(u□41* . %v1 □121□4 ( ) 1□%2□4. %%41□5 □4*
4(0)%%o1 (21&1□1A552□ □1*(u□41*.*

Resource	Max/Min Capacity (MW)	Full-Load Heat Rate (Btu/kWh)	Ramp Rate (MW/min)	Forced Outage Rate (%)	Maintenance Rate (%)	Start-up Time (hour)	Start-up Cost ($)
SCE NEW GT	100/40	9,191	12.0	7.24	10.0		1,200
SCE NEW CCGT	500/200	7,000	7.5	4.96	10.0	2	44,520
SDGE NEW CCGT	373/200	7,000	7.5	4.96	10.0	2	44,520
Gateway (CCGT)	530/265	7,000	10.0	10.00	10.0	2	24,411
Sentinel (GT)	106/43	9,191	12.0	10.00	10.0		1,000

* □(413 (u%1 □%1* (f□1 21& □1*(u□41* %1 b%13 (2 ; ER/ GA□□ 9006-90B0 %v1□%1 E□? R3, / / GT f(□ %o+=, *5z1* %23 GT f(□50)-u* =,



Monthly Capacity Factors

Resource	1	2	3	4	5	6	7	8	9	10	11	12	Annual
SCE	9.5	11.2	10.0	9.8	12.0	16.5	20.3	17.9	7.9	10.0	8.0	10.2	11.9
SCE	53.1	60.0	61.4	64.2	59.4	64.1	73.7	83.4	80.9	66.9	61.1	68.3	66.4
SDGE	49.2	62.1	55.9	20.4	72.6	76.5	69.0	87.4	83.7	50.9	37.8	20.3	57.1
Gateway	52.0	45.6	55.3	48.7	45.5	56.1	62.8	55.2	60.1	56.2	60.3	60.7	54.9
Sentinel	22.1	20.3	17.2	18.3	21.1	19.6	20.4	19.1	11.6	16.2	16.0	12.1	17.8
GT	10.9	10.7	8.0	10.8	10.9	12.0	11.2	9.5	6.6	8.4	9.3	10.4	9.8
CCGT	48.5	45.9	40.6	39.8	36.1	40.2	62.0	65.4	55.1	51.0	49.6	51.9	49.4

Ancillary Service and Load Following Contribution (GWh)

Resource	LF	LF	Non-Spin	Reg-D	Reg-U	Spin
SCE	23.9	537.3	1.9	32.1	320.0	914.8
SCE	1,888.0	849.2	0.5	101.8	11.6	577.2
SDGE	264.9	217.8	0.0	202.7	78.6	56.4

L/ R □1*(u□41* %1 . 5□. +y u□55z13.

- EA%0) +1 - u□55z%5(2 (f □/ E ; E, / / GT □1*(u□41
  - = %A4%) %45y: B,000 = , 69 A500 = , :
  - T(□%+) (**5b+1 □121□%5(2 52 9090: 7,774 AB,000 = 7,774 G, .
  - A22u%+4%) %45y f%4(□: 66.40% 65,733 G, . □121□%5(2:
  - U) &%3 A□ %23 +(%3 f(+(&52□4(2□5bu5(2: B,439 G, .
  - G121□%5(2) +u* A□ %23 L□4(2□5bu5(2: 7,97B G, .
  - T(□%+u□55z%5(2 □%1: 79.77%
  - □(□413 %23 0 %52□12%241 (u□%1 □%1: B4.96%
  - U2u□55z13 4%) %45y: 9.96%

A3355(2%+f+1A5b+1 4%) %45y 5* 211313 52 %3355(2 (.1 L/ R 1*(u41*.

- U) (B,95B = , 90-0 52 %0) 52 4%) %45y *. (%1 5312 55 513
- / (2*5* 12 &5. .1 f5235 2 * 52) 1v5(u* * u3y
  - ; 113 f(4,600 = , L= B00 GT 4%) %45y &5. z1 ((u%1 5312 55 513 52) 1v5(u* * u3y
  - 3,B73 = , L/ R 4%) %45y %3313
  - B,95B = , 1*5 3u%+*. (%1
  - A3355(2%+310 %23 1*) (2* 1 u* %1 f(0 13u413 0 525 0 u0 u2 50 1

I2 .1 *12* 55y5y 4%*1 1v12-b%*13 310 %23 1*)(2*1 4%) %45y 5* 13u413 by 40.7%.*

Region	Origin al DR Capacity (MW)	Reduced DR Capacity (MW)	Reduction (MW)
PG&E	1,687	732	955
SCE	2,827	1,977	850
SDGE	302	146	156
TOTAL	4,816	2,855	1,961

* E21 y u*%1 50 5* f(.1 310 %23 1*)(2*1 1*(u41* %1 2(13u413 *(*(0 1(f .1 1*(u41* 0 %y b1 31) (y13 f(0 (1 .(u*.

□10 %23 □1*)(2*1 □1*(u□41* %□1 u*13 f□1qu12□+y 52
u0 0 1□0 (2□..

Number of Hours DR Resources Deployed

Case	Jul	Aug	Sep	Oct	Sum
Original꿹□ηDR꿹□ηCapacity	44	22	3	2	71
Reduced꿹□ηDR꿹□ηCapacity	47	23	2	2	74

R%0) 52 4%) %45y *. (%1 524 1%*1* &5. 13u45(2 (f 310 %23 1*) (2*1 4%) %45y.

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California ISO
Shaping a Renewed Future

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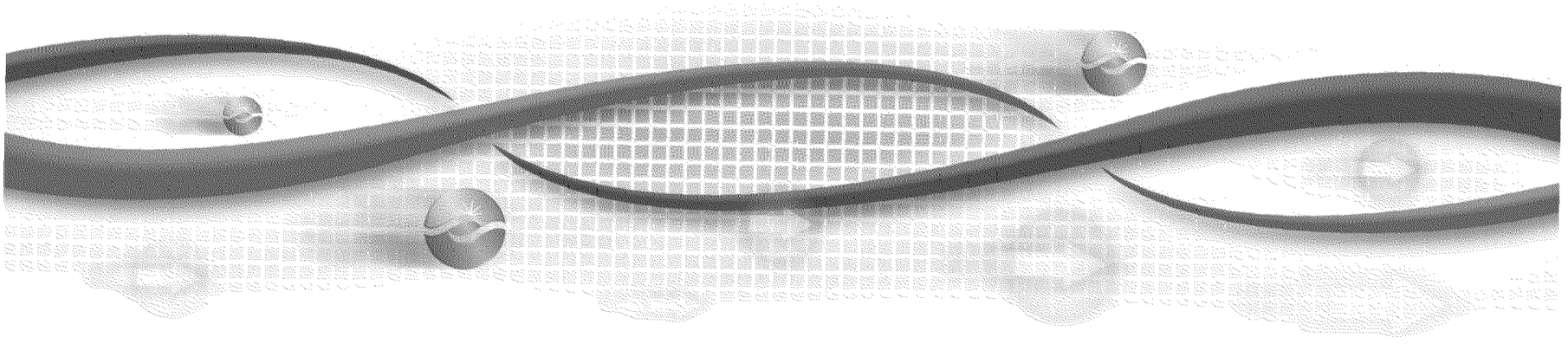

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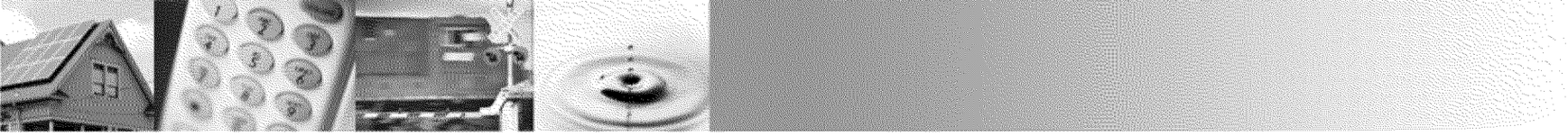


Scenarios and Assumptions

Nathaniel Skinner

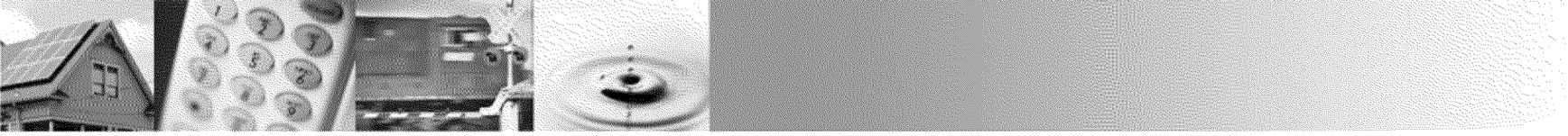
Senior Analyst, Generation & Transmission Planning

California Public Utilities Commission

September 19, 2012

Scenarios Purpose

- Inform policy-makers by providing information on a broad range of plausible future scenarios
- Inform bundled procurement plans and positions
- Inform the transmission planning process and analysis of operating flexibility
- Limit the range of analysis to conform with resource constraints, while meeting policy objectives for the current LTPP



Problem Statement

Scenarios should be developed to answer the following primary questions:

- What new infrastructure needs to be constructed to ensure adequate reliability?
- What mix of infrastructure minimizes cost to customers over the planning horizon?

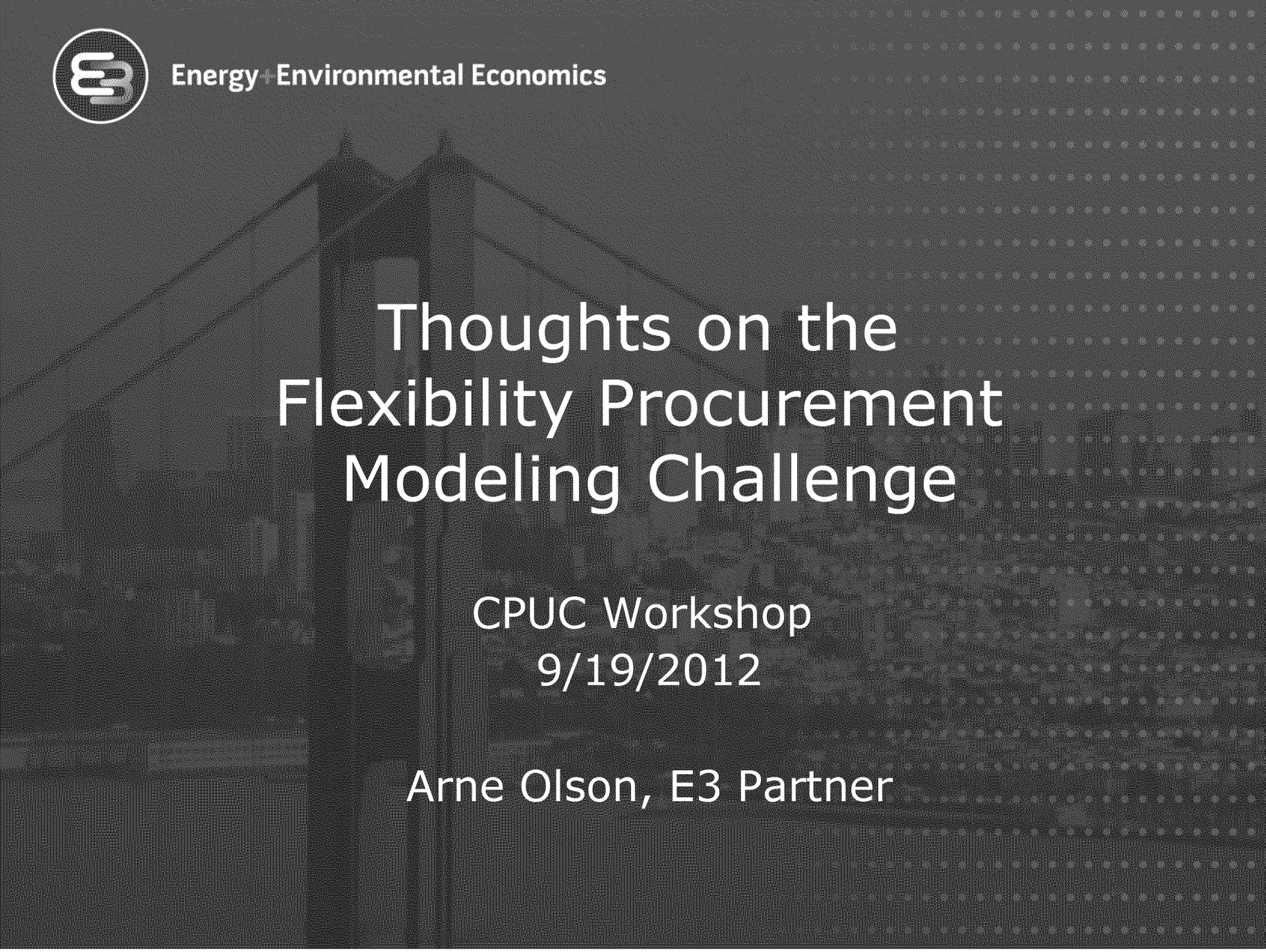
Planning Area & Period

- CAISO controlled transmission grid & distribution systems
- Period 1 – 10 years ahead
  - T(3%y □ □(u□. 9099
- Period 2 – 20+ years ahead
  - 2023 through 2034
  - Simplified analysis to understand impacts of choices made to meet Period 1 needs

Example Scenario: 1 - Base

- Reflect expectations of the future with little change from existing policies
- Key Assumptions:
  - Mid load, mid inc. EE, mid small PV, low CHP
  - Mid DR, high probability additions, commercial RPS
  - Retirements: Low nuclear, low hydro/wind/ solar, mid other

How to get there: No change to business as usual and programs achieve results consistent with forecast expectations



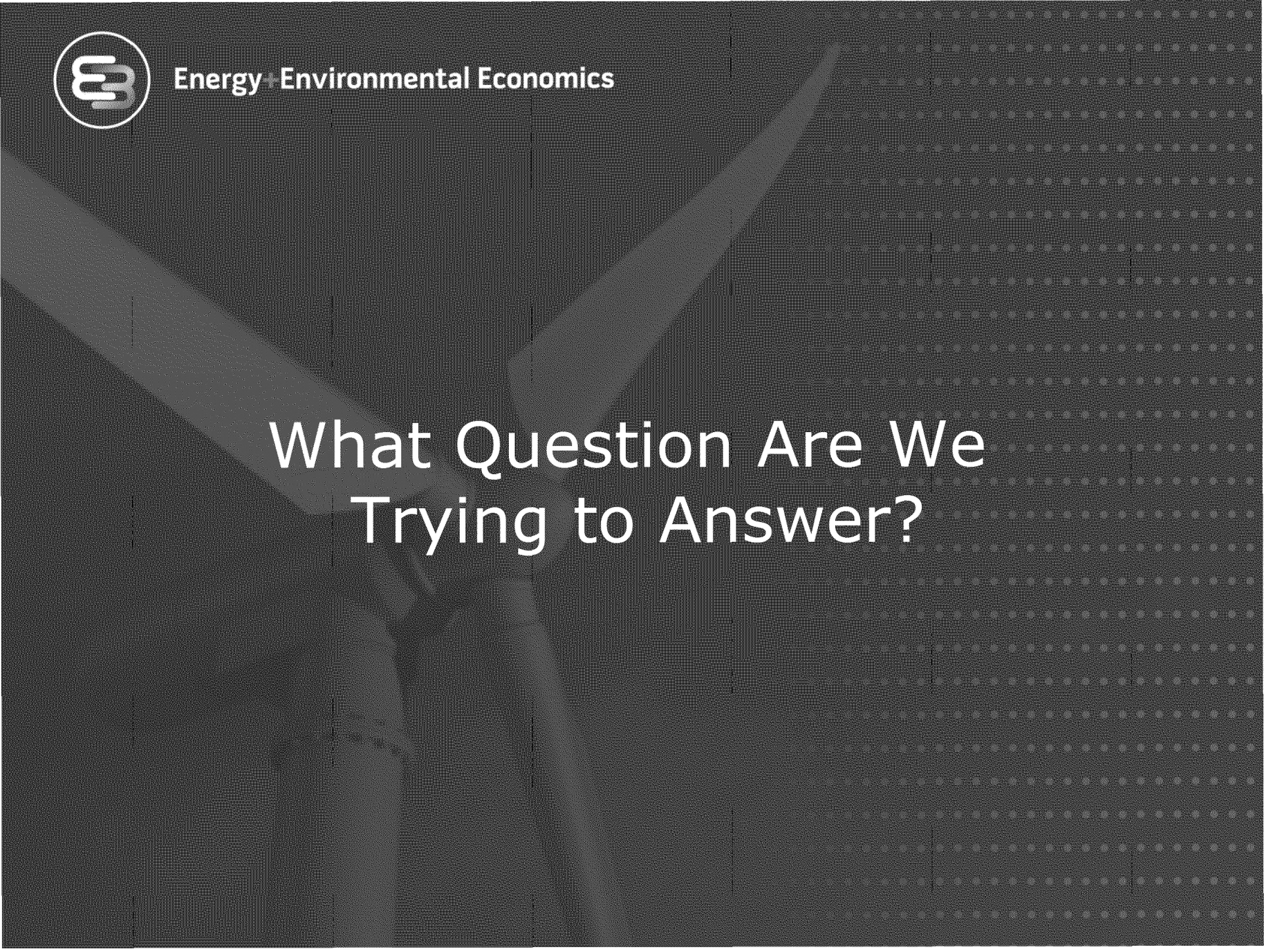
Thoughts on the Flexibility Procurement Modeling Challenge

CPUC Workshop
9/19/2012

Arne Olson, E3 Partner

Agenda

- What Question Are We Trying to Answer?
- What Tools Are Available Today?
- What Would a Hybrid Model Look Like?

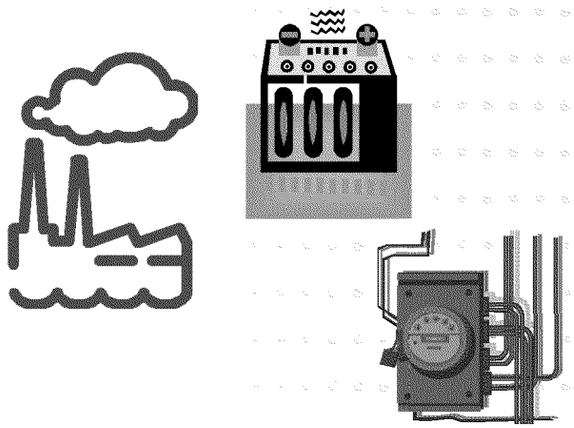


What Question Are We Trying to Answer?

Today's Planning Problem Has Two Related Questions

1. How many MW of dispatchable resources do we need to (a) meet load, and (b) meet ramping requirements on various time scales?

2. What is the optimal mix of new resources, given the characteristics of the existing fleet?



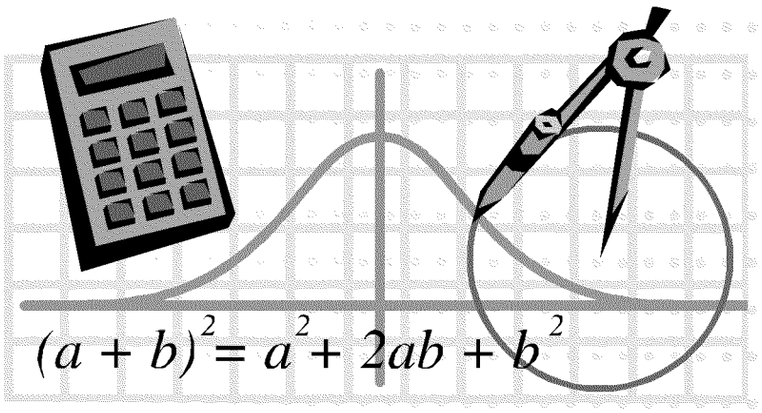
Energy+Environmental Economics

Answer is a Matter of Matching Demand and Supply

- **Demand is a function of a number of variables:**
  - Load
  - Load forecast error
  - Load variability
  - Expected renewable production
  - Expected renewable production forecast error
  - Expected renewable production variability
- **Supply is the ability of the fleet of dispatchable resources to respond on the appropriate time scale**

Problem is Stochastic in Nature

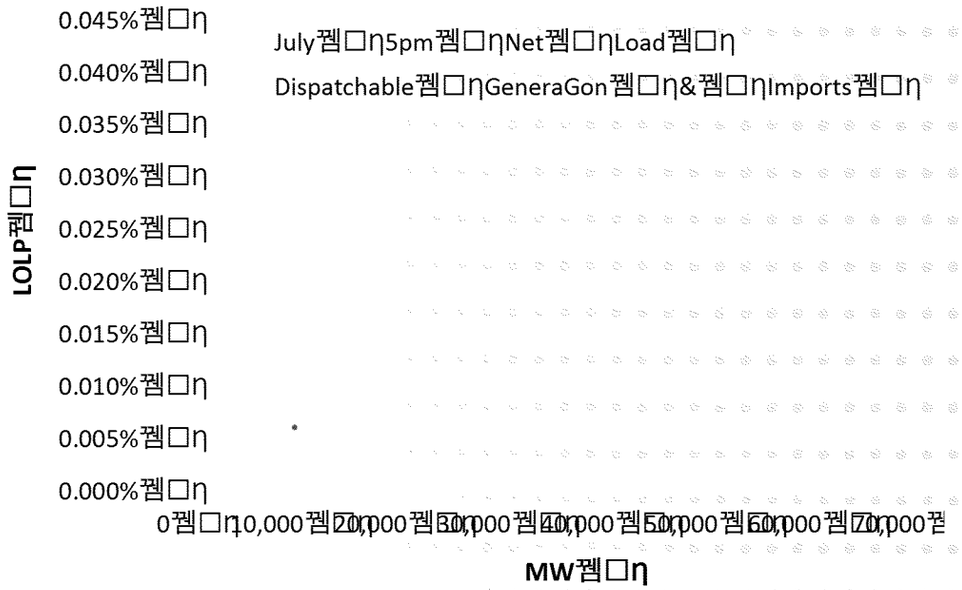
- **Load is stochastic, variable and uncertain**
  - Often characterized as "1-in-5" or "1-in-10"
  - Subject to forecast error

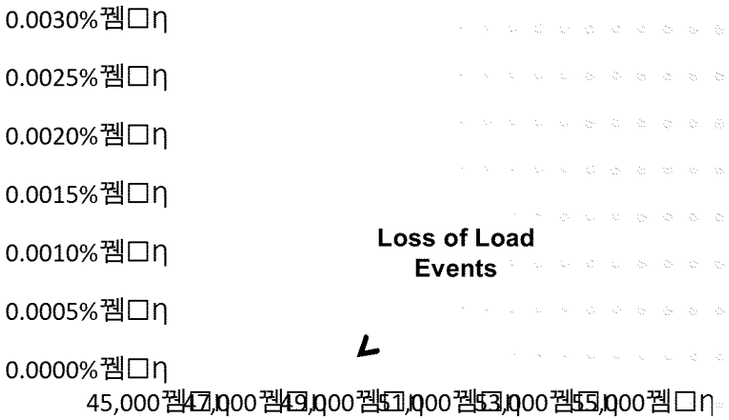


- **Renewable output is also stochastic, variable and uncertain**
- **Supplies can also be stochastic**
  - Hydro endowment varies from year to year
  - Generator forced outages are random
- **Need to know size, probability and duration of any shortfalls**

Stochastic Modeling Must be Robust

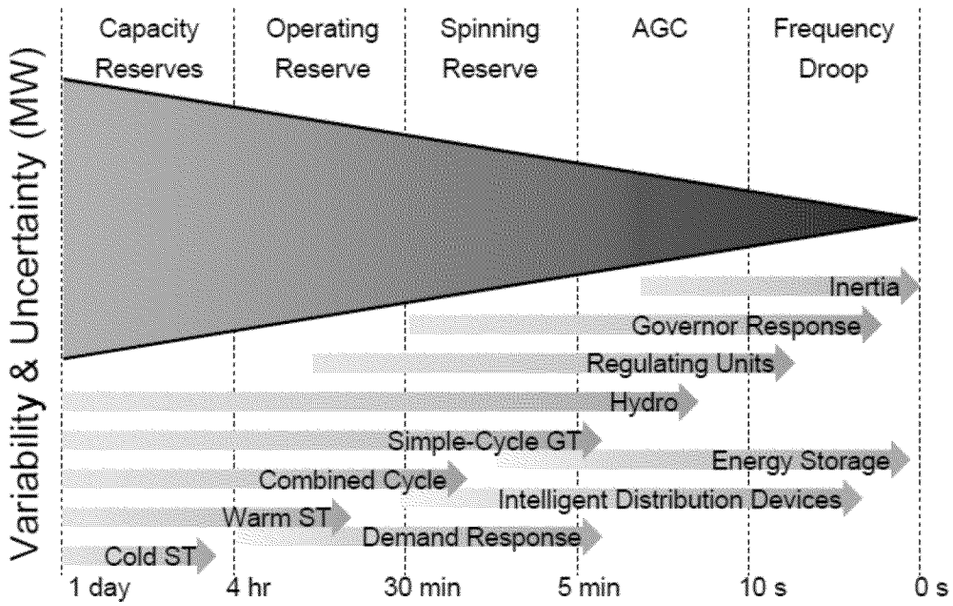
- **Need will occur during "tail" events for both demand and supply**
  - Need enough iterations to accurately capture low-probability events
- **Flexibility need shortages will be related to capacity shortages**
  - Inflexible capacity can be a substitute for flexible capacity under some circumstances





Need Must Be Defined on a Number of Time Scales

- **Peak Load is an annual phenomenon**
  - Loss of Load can occur in 50-250 hours per year
  - Typically measured on an hourly basis
- **Ramping needs must be defined over much smaller time increments**
  - 5 hours
  - 1 hour
  - 20 minutes
  - 5 minutes
  - 1 minute



Source: Russ Philbrick, PES General Meeting, Detroit, July 2011


Energy+Environmental Economics
What Tools are Available Today?

Planning Models

+ Calculate Loss-of-Load Probability (LOLP) and related metrics to determine the probability that resources will be inadequate to meet peak loads

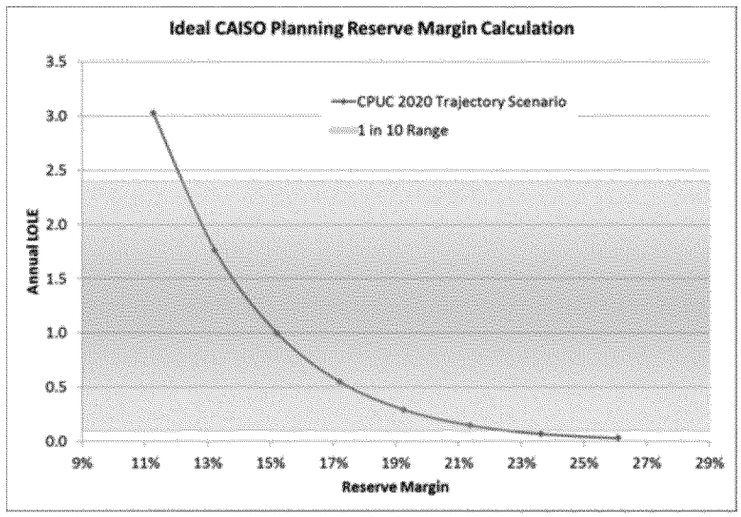
- Conducted to support calculation of a reserve margin or to determine least-cost expansion plan

+ Advantages

- Stochastic model that considers the full range of load conditions

+ Limitations

- Ignores operations
  - In the past, planning to prevent loss of load has provided enough flexibility

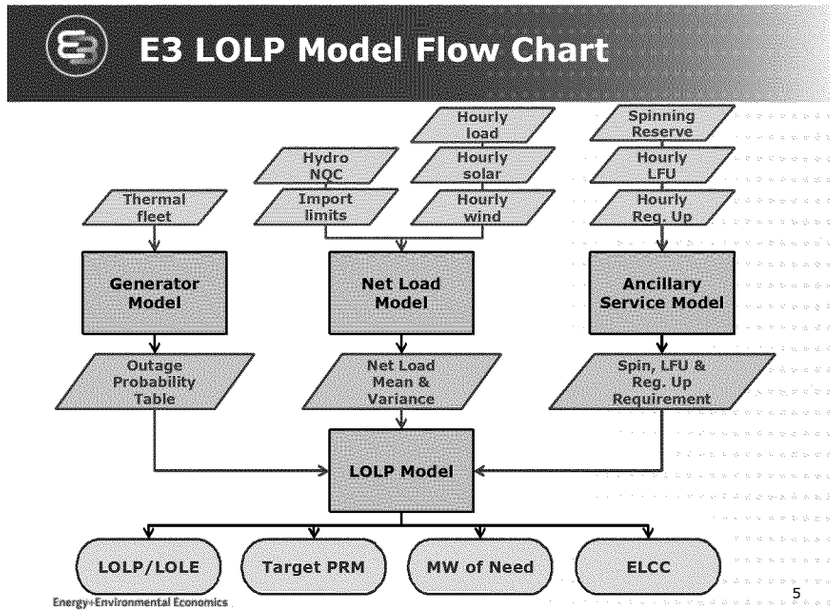


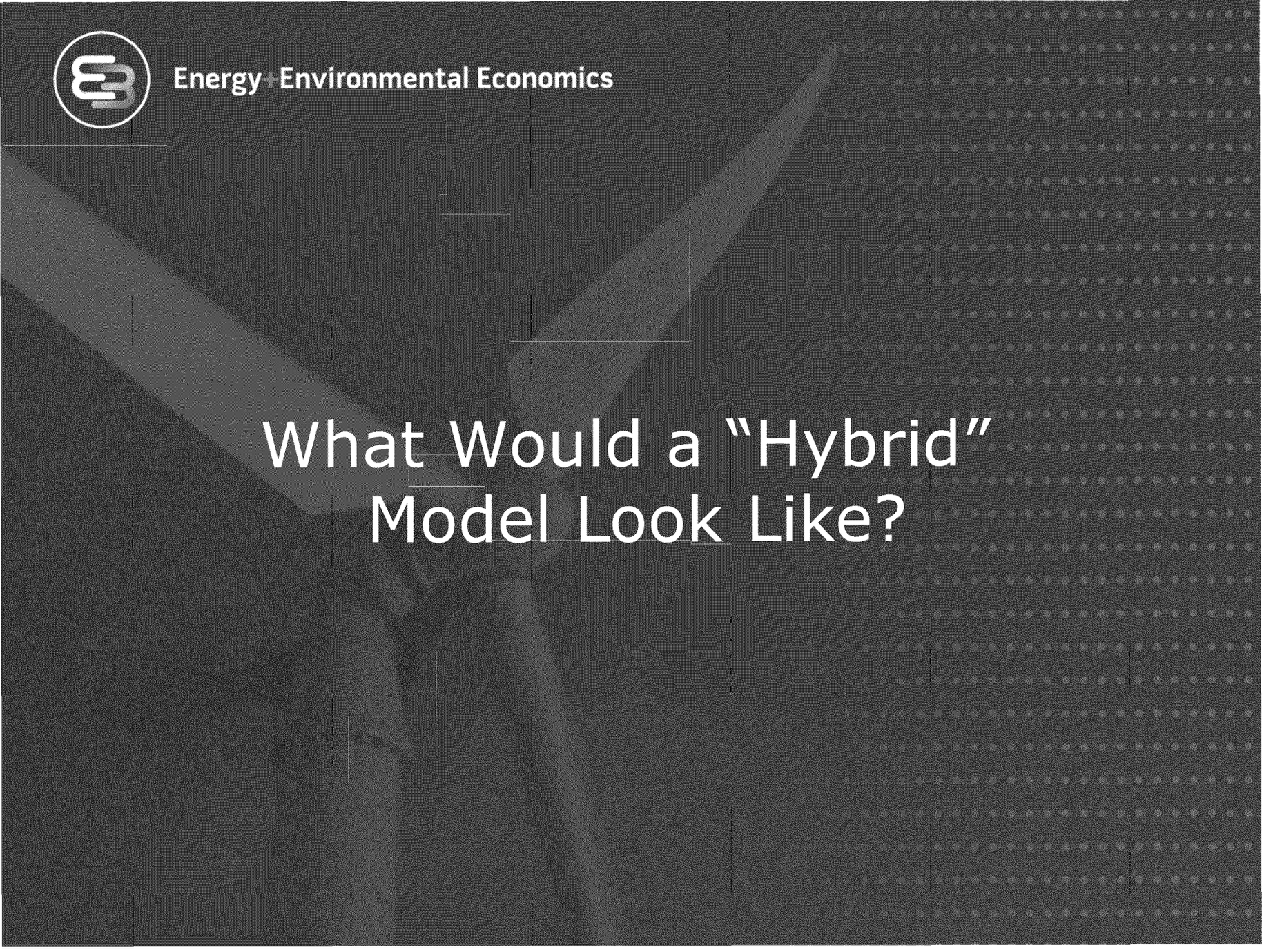
Operations Models

- **Production simulation models minimize operating costs subject to constraints on unit availability, transmission availability, etc.**
  - Conducted to determine the total cost associated with meeting electric load over 8760 hours
- **Benefits**
  - Treats details of generator operating limitations, transmission, and time-sequential behavior
- **Limitations**
  - Deterministic
  - Significant unnecessary detail
  - Lengthy run time

Enhanced Planning Models

- **E3's LOLP/ELCC Model incorporates reserves into LOLP framework**
- **Does not treat flexibility characteristics explicitly**
  - Flexibility need modeled as fixed hourly parameter
  - Does not measure ability of fleet to meet flexibility needs
  - Requires reference to a portfolio that is assumed to be sufficiently flexible (All-Gas Case)

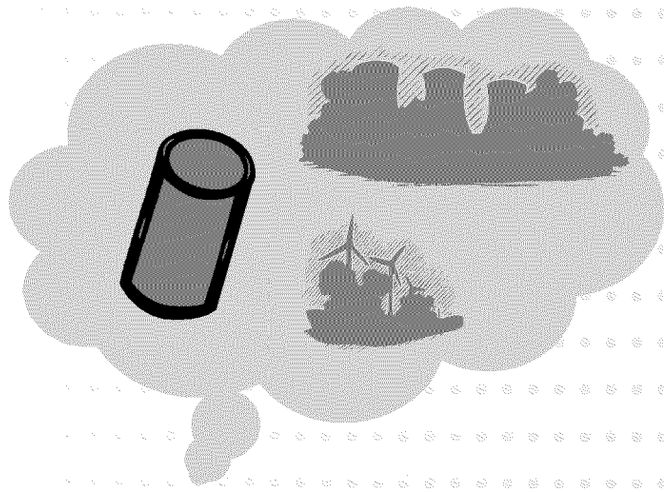




What Would a "Hybrid" Model Look Like?

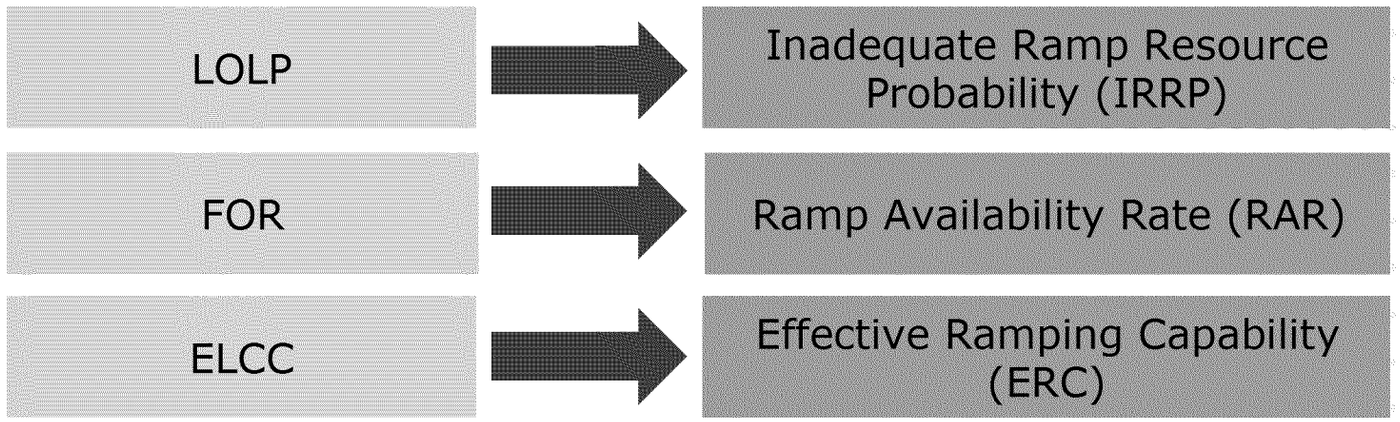
Planning for Reliable Operations

- **A model is needed that plans for reliable system operations, satisfying:**
  - Capacity Requirement – according to traditional metrics for capacity planning
  - Flexibility Requirement – accounting for the limitations of the fleet in time sequential operations
- **Measures taken to meet need in one category may satisfy need in the other**
  - The model should select the least-cost array of portfolio/operational changes to meet flexibility
  - Differentiated value of resource types over different time scales should be captured
    - Storage provides fast response ramping over short time periods, CCGTs provide capacity and ramp, etc.



Flexibility Requirement – Defining new set of metrics

- **Attempts to quantify unit flexibility (NERC's IVGTF Task 1.4)**

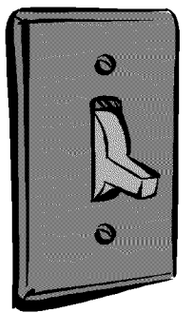


- **Still unanswered: How could these metrics be used in a procurement process?**
  - How would standards be determined and adopted?
  - Is there a way to compare flexibility with adequacy using a common currency?

Best solution to satisfy need

+ **Two options to mitigate flexibility violations:**

Flip a switch



+ **Operational changes can mitigate flexibility shortfalls**
  - Reserve scheduling, "pre-curtailment" of renewables

Grab a shovel

+ **Steel in the ground can help to meet both capacity and flexibility requirements**
  - Fast, expensive resources vs. cheaper, slower ones

+ **A useful model will be able to quantify the trade-offs between these options**
  - What measure or combination of measures satisfies need?

The "Sledgehammer" Approach: Stochastic Production Simulation

- **Minutely time step resolution**
- **Monte Carlo for forecast errors**
- **Requires large datasets**
  - Detailed load, wind, solar datasets
  - Individual unit specifications
  - Scheduled and forced outages
  - Hydro and import conditions

Challenges

- **Run time: full stochastic simulation may be impractical**
- **Year-long simulation does not capture long-term uncertainties, important for planning analysis**
- **Flexibility of system depends on chosen reserve requirements – possibility of "false violation"**
- **Difficult to incorporate expansion decision**

One Path Forward: Reduced-Form Production Simulation Modeling

- **Three key modifications to production simulation modeling framework:**

  1. **Stochastic operations:** Run thousands of draws of a single day per month to accurately characterize long-term uncertainty
     - Preserve time-sequential unit commitment and operations over 24 hours
  2. **Endogenous reserves:** Include endogenous, minutely specification of reserve flexibility requirements to avoid false violations and accurately characterize fast-ramping resource
  3. **Expansion decisions:** Incorporate operational and expansion decisions (with fixed costs) to find optimal solutions

+

- **Requires elimination of *all* detail that doesn't help answer question at hand in order to minimize run time (e.g., transmission)**

Energy + Environmental Economics

Thank You!

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Wrap Up & Next Steps

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California Public Utilities Commission

September 19, 2012

Operating Flexibility #3

- Planning for an early November third workshop
  - Would explore the path forward for operating flexibility analyses and interpreting these needs into the LTPP
  - In person or fully over WebEx?

Calendar

September

19: Track II Final Scenarios to be sent to service list

24: Track I Briefs Due

October

5: Track II Final Scenarios Comments Due
LTPP/Energy Storage Workshop Comments Due

12: Track I Reply Briefs Due

19: Track II Final Scenarios Reply Comments Due
LTPP/Energy Storage Workshop Reply Comments Due

Calendar

November

2: Track III Rules Comments Due [PENDING ALJ RULING]

20: Track II Scenarios PD

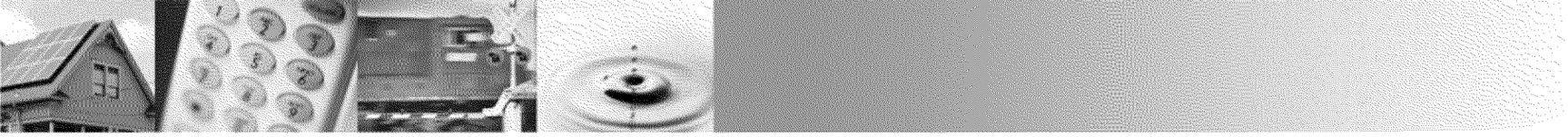
December

12: Track I PD

20: Track II Scenarios Decision on Agenda

January

TBD Commission Meeting: Track I Decision on Agenda



Thank you!
For Additional Information:

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