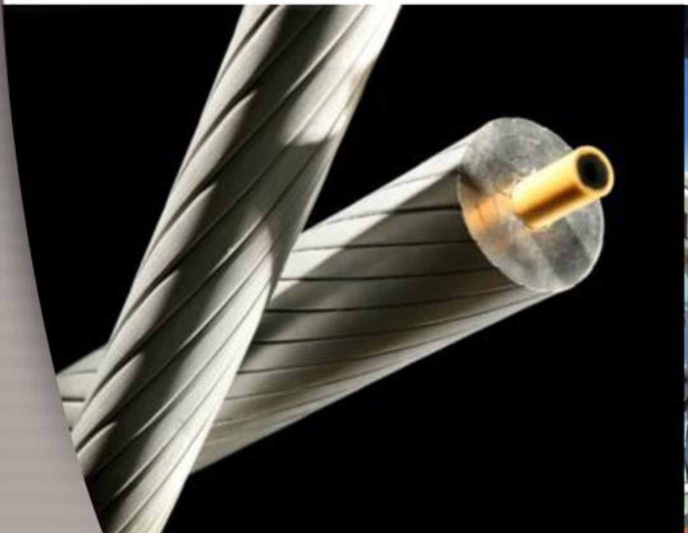
How the choice of transmission conductor can reduce greenhouse gas emissions.



What is the scope of the impact?

Complete conversion of the US grid to efficient conductor would eliminate 44 million metric tons of CO_2 due to the reduction of line losses by 20 to 40% compared to ACSR conductors of the same diameter and weight under equal load conditions:

(1)30% reduction of

(2) 6% line losses typical of ACSR conductor,

(3) saves or adds 71.8 million MWh of power generation,

(4)which at an average of 1.37 pounds of CO_2 per kWh,

(5)results in 44 million metric tons reduction of CO2 per year, or alternatively,

(6)The effective generation/delivery of 8,199 MW of power for consumers.

	Potential Impact of US Conversion to Efficient Conductors		
	US Consumption	3,990,000,000,000	kWh
2	Transmission Line Losses (6%)	239,400,000,000	kWh
1	30% Reduction with ACCC	71,820,000,000	kWh
3	MWh Equivalent Savings (Annual)	71,820,000	MWh
6	**Generation Equivalent Delivered**	**8,199**	**MW**
	annual economic value @ $50/MWh	$3.591	billion
4	US Average CO2 Emmision	1.372	lbs/kWh
5	**Annual CO2 Reduction with ACCC**	**44,688,000**	**Metric Tons**

CTC GLOBAL

Technical aspects of efficiency

- The more aluminum in a conductor the better
- The higher the %IACS of the aluminum the better
- Annealing improves conductivity and resistivity
- Conductivity and Resistivity are correlated

Conductor Properties		Conductive Strands			Core Strands			
Code Name	Conductor Description	aluminum type	tensile strength	conductivity (%IACS)	type	tensile strength	modulus	CTE
AAC	All Aluminum Conductor	1350-H19	24- 28 ksi	61.2	1350-H19	24-28 ksi	10 msi	23.0
AAAC	All Aluminum Alloy Conductor	6201-T81	46-48 ksi	52.5	6201-T81	46-48 ksi	10 msi	23.0
ACAR	Aluminum Conductor Al Alloy Reinforced	1350-H19	24- 28 ksi	61.2	6201-T81	46-48 ksi	10 msi	23.0
ASCR	Aluminum Conductor Steel Reinforced	1350-H19	24- 28 ksi	61.2	coated steel	200-220 ksi	29 msi	11.5
AACSR	Aluminum Alloy Conductor Steel Reinforced	6201-T81	46-48 ksi	52.5	coated steel	200-220 ksi	29 msi	11.5
ACSS	Aluminum Conductor Steel Supported	1350-O	~8.5 ksi	63.0	coated steel	220-285 ksi	29 msi	11.5
ACIR	Aluminum Conductor Invar Reinforced	Al-Zr alloy	23-26 ksi	60.0	invar steel	150 - 155 ksi	22 msi	3.7
ACCR	Aluminum Conductor Composite Reinforced	Al-Zr alloy	23-26 ksi	60.0	metal matrix	190 ksi	32 msi	6
ACCC	Aluminum Conductor Composite Core	1350-O	~8.5 ksi	63.0	carbon hybrid	310-360 ksi	16-21 msi	1.6

Factors in selecting conductors

- Any given set off towers has limits to weight, diameter, and sag clearance of the conductor whether a new line design or replacement of conductor on existing towers.
  - Weight – impacts tension on towers
  - Tension – limited by towers and crossarms
  - Diameter – mostly impacts wind and ice loads
  - Sag – clearance at temperature (and ice/wind load)
  - Operating amps – establishes expected temperature and sag
- For comparison it is fair to keep upper limits on design factors for towers/conductors.

Reconductoring Kumbotsu - Danagundi Transmission Line

CTC GLOBAL

- **Reconductoring: Kumbotsu – Danagundi 132vV T/L**
  - Objective: Deliver 600A while maintaining clearance
  - Large increase could not be handled by ACSR Wolf (400A)
- **Project Requirements (Limitations)**
  - Use existing towers with only maintenance repairs
  - Meet sag requirement of 10 meters (current sag allowance for ACSR Wolf)
- **Project Analysis**
  - Select best performance options from ACSR, ACSS, STACIR, AAAC and ACCC
  - Compare conductor cost based on sizing of capacity and sag requirements

Making a project comparison with CCP™ Software

CTC GLOBAL

1. Nine areas for inputs, conductor selection and outputs.
   1. Environment
   2. Line factors/Cost factors
   3. Sag calculation factors
   4. Ice/wind conditions
   5. Conductor selection
   6. Temperature and line loses
   7. Sag and tension results
   8. Visual sag and limits
   9. Efficiency and emissions
2. All yellow cells are inputs, can enter own value or choose from dropdown list
3. Clearly demonstrates how conductor selections impact a project.

CTC GLOBAL

Input Company and/or Project Name

Conductor Information (3)

Type:		ACCC®		ACSR		STACIR-AW
Size (mm² Al - Code Word):		520 - DRAKE		403 - DRAKE		413 - 410
Aluminum Area (mm²):		519.7		402.8		413.4
Diameter (mm):		28.143		28.143		28.500
Rated Strength (kN):		183		140		125
Weight (kg/km):		1,565.0		1,627.8		1,625.8
DC Resistance at 20°C (ohms/km):		0.05362		0.07015		0.06860
AC Resistance at 25°C (ohms/km):		0.05543		0.07245		0.07045
AC Resistance at 75°C (ohms/km):		0.06618		0.08637		0.08271
Conductors per phase:		1		1		1
Circuits:		1		1		1
Ampacity (A) at Temperature (°C):	70	978	70	856	70	877
Ampacity (A) at Rated Operating Temp (°C):	180	1,786	75	908	210	1,758
Ampacity (A) at Maximum Temp (°C):	200	1,884	100	1,120	240	1,883

Line Loss (6)

Steady-State Temperature (°C) at Peak Ampacity:	61	70	68
First Year Line Losses (MWh):	10,205	13,734	13,096
ACCC® 520 - DRAKE - Reduces First Year CO_2 Generated by (MT):		452	370
ACCC® 520 - DRAKE - Reduces First Year Line Losses by (MWh):		3,529	2,891
ACCC® 520 - DRAKE - Reduces First Year Line Losses by (%):		26%	22%
ACCC® 520 - DRAKE - Reduces First Year Line Losses by ($/Year):		352,897	289,086
ACCC® 520 - DRAKE - Line Loss Savings per meter of Conductor ($/m):		7.31	5.99

(9)

ACCC® 520 - DRAKE - Reduces 30 year line loss by ($):		10,586,899	8,672,570
ACCC® 520 - DRAKE - Reduces 30 year CO_2 generation by (MT):		29,886	24,482

Revenue Attainable during Peak Capacity (Limited by Max Sag)

Peak Power Available for Delivery (10 hrs.) (MWh):	4,149	2,439	2,093
Potential Revenue for Power Delivered ($):	3,319,010	1,951,242	1,674,522

Initial Sag and Tension:

% RTS:	19%	25%	24%
Sag at Initial Sagging Temperature (m):	5.12	5.30	6.19
Initial Tension at Sagging Temperature (kN):	34.8	35.0	29.9

Sag/Tension at Above Stringing Temperature: (7)

Sag at Peak Operating Amps	Temp(°C):	61	70	68
	Sag (m):	6.63	7.11	7.79
	Tension (kN):	26.9	26.1	23.8
Sag at Rated Operating Temperature	Temp(°C):	180	75	210
	Sag (m):	7.18	7.29	9.75
	Tension (kN):	24.8	25.4	19.0
Sag at Maximum Temperature	Temp(°C):	200	100	240
	Sag (m):	7.22	8.16	9.90
	Tension (kN):	24.7	22.7	18.7
Temperature at Maximum Allowable Sag	Max. Temp(°C):	200	96	75
	Sag (m):	7.22	8.03	8.02
Ampacity Cells Turn Red if Max Capacity is not reached	Tension (kN):	24.7	23.1	23
	Ampacity (A):	1,884	1,090	931

Wind / Ice or Cold Temperature Sag/Tension:

Sag (m):	7.44	6.49	7.02
Tension (kN):	46.8	54.7	50.7

Units	Language	Voltage Type
Metric	English	AC

CCP v 2.1.0

Environmental Input (1)

Set Default Environmental Inputs

1032.1	Sun Radiation (W/m²)
25	Ambient Temp. (°C)
0.61	Wind (m/sec)
0	Elevation (m)
0.5	Solar Absorptivity
0.5	Emissivity
90	Wind Angle (deg.)
0	Azimuth of Line (NS=0, EW=90)
32	Latitude (neg = South)
June	Month
21	Day of Month
12	Time (24 hrs.)
Clear	Atmosphere

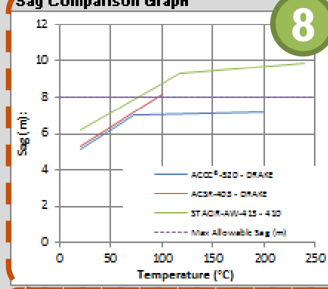
Load and Generation Cost Assumptions (2)

16.1	Line Length (km)
132	Voltage (kV)
856	Peak Op. Amps
70%	Load Factor
52%	Loss Factor
196	Peak Power per Circuit (MW)
3	Phases/Circuit
100	Cost of Energy Generation ($/MWh)
0.282	CO_2 (kg/kWh)
0%	Load Increase/Year
10	Hours/Year at Peak Capacity (hr.)
800	Price of Energy at Peak Capacity ($/MWh)

Initial Sag and Tension: (5)

304.8	Ruling Span (m)
21	Initial Sagging Temperature (°C)
8.0	Maximum Allowable Sag (m)

Sag Comparison Graph (8)



Wind / Ice Conditions (4)

-5	Temperature (°C)
16.1	Windspeed (km/hr)
0.00	Safety Factor (N/m)
12.70	Radial Ice Thickness (mm)
912.9	Ice Density (kg/m³)

CTC GLOBAL

I Initial T/L operating condition and target

Units	Language	Voltage Type	
Metric	English	AC	CCP v 2.3.2

Environmental Input (Set Default Environmental Inputs)

1029.6	Sun Radiation (W/m²)
35	Ambient Temp. (°C)
0.61	Wind (m/sec)
100	Elevation (m)
0.5	Solar Absorptivity
0.5	Emissivity
90	Wind Angle (deg.)
0	Azimuth of Line (NS=0, EW=90)
9	Latitude (neg = South)
February	Month
15	Day of Month
12	Time (24 hrs.)
Clear	Atmosphere

Load and Generation Cost Assumptions

10.0	Line Length (km)
132	Voltage (kV)
400	Peak Operating Amps
70%	Load Factor
52%	Loss Factor
91	Peak Power per Circuit (MW)
3	Phases/Circuit
50	Cost of Energy Generation ($/MWh)
0.200	CO_2 (kg/kWh)
0%	Load Increase/Year

Initial Sag and Tension:

350	Ruling Span (m)
30	Initial Sagging Temperature (°C)
10.0	Maximum Allowable Sag (m)

1 — Existing Line Condition

50% increase in peak amps, with reduced load factor

Load and Generation Cost Assumptions

10.0	Line Length (km)
132	Voltage (kV)
600	Peak Operating Amps
50%	Load Factor
29%	Loss Factor
137	Peak Power per Circuit (MW)
3	Phases/Circuit
50	Cost of Energy Generation ($/MWh)
0.200	CO_2 (kg/kWh)
0%	Load Increase/Year

Initial Sag and Tension:

350	Ruling Span (m)
30	Initial Sagging Temperature (°C)
10.0	Maximum Allowable Sag (m)

2 — Minimum Increase Target

- In #1, we see that the Kumbotsu – Danagundi transmission line is operating at 400 amps, delivering 91 MW of power, which is the maximum rating for the ACSR Wolf conductor.
- In # 2, we see the minimum up-rating target of 600 amps (137 MW) which will be the basis for conductor selection and performance comparison.

2 Baseline capacity of ACSR Wolf

CTC GLOBAL

CTC GLOBAL

Kumbotsu – Danagundi: ACSR Wolf baseline

Conductor information	Base Conductor	Conductor #1	Conductor #2
Type:	ACSR	Select Type	Select Type
Size (mm² Al - Code Word):	158 - WOLD	0 - Select Size	0 - Select Size
Aluminum Area (mm²):	158.1	0.0	0.0
Diameter (mm):	18.130	0.000	0.000
Rated Strength (kN):	69	0	0
Weight (kg/km):	726.0	0.0	0.0
DC Resistance at 20°C (ohms/km):	0.17875	0.00000	0.00000
AC Resistance at 25°C (ohms/km):	0.18285	0.00000	0.00000
AC Resistance at 75°C (ohms/km):	0.21881	0.00000	0.00000

2

3

		Base Conductor		Conductor #1		Conductor #2
Conductors per phase:		1		0		0
Circuits:		1		0		0
Ampacity (A) at Temperature (°C):	70	416	0	#VALUE!	0	#VALUE!
Ampacity (A) at Rated Operating Temp (°C):	7	449	###	#VALUE!	###	#VALUE!
Ampacity (A) at Maximum Temp (°C):	100	577	###	#VALUE!	###	#VALUE!

Line Loss (Based on Inputted Peaking Operating Amps Value)

	Base Conductor	Conductor #1	Conductor #2
Steady-State Temperature (°C) at Peak Ampacity:	68	#VALUE!	#VALUE!
Resistance at Peak Operating Amps (ohm/km):	0.21353	#VALUE!	#VALUE!
First Year Line Losses (MWh):	4,682	#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces First Year CO_2 Generated by (MT):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by (MWh):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by (%):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by ($/Year):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Line Loss Savings per meter of Conductor ($/m):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces 30 year line loss by ($):		#VALUE!	#VALUE!
ACSR 158 - WOLD - Reduces 30 year CO_2 generation by (MT):		#VALUE!	#VALUE!

Units	Language	Voltage Type
Metric	English	AC

CCP v 2.3.2

Environmental Input

Set Default Environmental Inputs

1029.6	Sun Radiation (W/m²)
35	Ambient Temp. (°C)
0.61	Wind (m/sec)
100	Elevation (m)
0.5	Solar Absorptivity
0.5	Emissivity
90	Wind Angle (deg.)
0	Azimuth of Line (NS=0, EW=90)
9	Latitude (neg = South)
February	Month
15	Day of Month
12	Time (24 hrs.)
Clear	Atmosphere

Load and Generation Cost Assumptions

1

10.0	Line Length (km)
132	Voltage (kV)
400	Peak Operating Amps
70%	Load Factor
52%	Loss Factor
91	Peak Power per Circuit (MW)
3	Phases/Circuit
50	Cost of Energy Generation ($/MWh)
0.200	CO_2 (kg/kWh)
0%	Load Increase/Year

ACSR Wolf is the basis for current capacity and limitations of the transmission line

2 ACSR Wolf establishes sag/tension limitations

CTC GLOBAL

Kumbotsu – Danagundi: ACSR Wolf baseline

Conductor information

		Base Conductor	Conductor #1	Conductor #2
	Type:	ACSR	Select Type	Select Type
	Size (mm² Al - Code Word):	158 - WOLD	0 - Select Size	0 - Select Size
Initial Sag and Tension: 1				
	% RTS:	20.0%	0.0%	0.0%
	Sag at Initial Sagging Temperature (m):	7.90	#N/A	#N/A
	Initial Tension at Sagging Temperature (kN):	13.8	#N/A	#N/A
Sag/Tension at Above Stringing Temperature:				
	Temp(°C):	68	#VALUE!	#VALUE!
Sag at Peak Operating Amps	Sag (m):	9.34		
	Tension (kN):	11.7		
2	Temp(°C):	75	#N/A	#N/A
Sag at Rated Operating Temper...	Sag (m):	9.61	#VALUE!	#VALUE!
	Tension (kN):	11.4	#N/A	#N/A
	Temp(°C):	100	#N/A	#N/A
Sag at Maximum Temperature	Sag (m):	10.50	#VALUE!	#VALUE!
	Tension (kN):	10.4	#N/A	#N/A
	Max. Temp(°C):	86	#VALUE!	#VALUE!
Temperature at Maximum Allowable Sag	Sag (m):	10.01	#VALUE!	#VALUE!
Ampacity Cells Turn Red if Max Capacity is not reached	Tension (kN):	10.9	#N/A	#N/A
	Ampacity (A):	511		
Wind / Ice or Cold Temperature Sag/Tension:				
	Sag (m):	8.44	#VALUE!	#VALUE!
	Tension (kN):	18.0	#N/A	#N/A

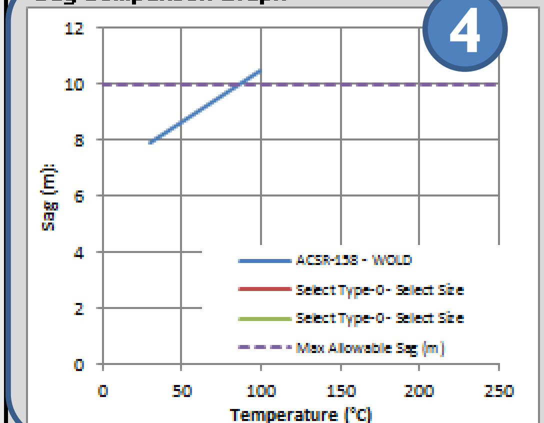
Units	Language	Voltage Type	
Metric	English	AC	CCP v 2.3.2

Environmental Input

Initial Sag and Tension: 3

350	Ruling Span (m)
30	Initial Sagging Temperature (°C)
10.0	Maximum Allowable Sag (m)

Sag Comparison Graph 4



Wind / Ice Conditions

20	Temperature (°C)
90.0	Windspeed (km/hr)
0.00	Safety Factor (N/m)
0.00	Radial Ice Thickness (mm)
0.0	Ice Density (kg/m³)

ACSR Wolf establishes the limits for installation tensile loads on the towers and the maximum sag of the conductors

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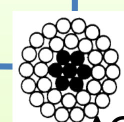
Mapping conductors within limitations

CTC GLOBAL

Tension needed to meet sag clearance (13.8kN = 1.4MT)

Because the towers were built for ACSR Wolf, we must only consider comparison of conductors that are very close to it's weight and diameter, and can be installed to meet the ground clearance.



ACSR Wolf
158.1 mm^2 aluminum
18.13 mm diameter
726 kg/km
13.8 kN installed tension

Weight (726 kg/km)

However, since ACSR Wolf cannot meet 600 amps, we will use these parameters to look at larger ACSR conductor.

3 ACSR Bear meets amps target but weighs 66% more

CTC GLOBAL

Kumbotsu – Danagundi: ACSR OPTIONS

Conductor information		Base Conductor		Conductor #1		Conductor #2
Type:		ACSR		ACSR		Select Type
Size (mm² Al - Code Word):		158 - WOLD		265 - BEAR		0 - Select Size
Aluminum Area (mm²):		158.1		264.5		0.0
Diameter (mm):		18.130		23.450		0.000
Rated Strength (kN):		69		[illegible]		0
Weight (kg/km):		726.0		1,213.0		0.0
DC Resistance at 20°C (ohms/km):		0.17875		0.10685		0.00000
AC Resistance at 25°C (ohms/km):		0.18285		0.10970		0.00000
AC Resistance at 75°C (ohms/km):		0.21881		0.13110		0.00000
Conductors per phase:		1		1		0
Circuits:		1		1		0
Ampacity (A) at Temperature (°C):	70	416	70	573	0	#VALUE!
Ampacity (A) at Rated Operating Temp (°C):	75	449	75	619	###	#VALUE!
Ampacity (A) at Maximum Temp (°C):	100	577	100	801	###	#VALUE!

Line Loss (Based on Inputted Peaking Operating Amps Value)

	Base Conductor	Conductor #1	Conductor #2
Steady-State Temperature (°C) at Peak Ampacity:	105	73	#VALUE!
Resistance at Peak Operating Amps (ohm/km):	0.24074	0.13017	#VALUE!
First Year Line Losses (MWh):	6,548	3,541	#VALUE!
ACSR 158 - WOLD - Reduces First Year CO_2 Generated by (MT):		-273	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by (MWh):		-3,007	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by (%):		-85%	#VALUE!
ACSR 158 - WOLD - Reduces First Year Line Losses by ($/Year):		-150,370	#VALUE!
ACSR 158 - WOLD - Line Loss Savings per meter of Conductor ($/m):		-5.01	#VALUE!
ACSR 158 - WOLD - Reduces 30 year line loss by ($):		-4,511,085	#VALUE!
ACSR 158 - WOLD - Reduces 30 year CO_2 generation by (MT):		-18,044	#VALUE!

Units	Language	Voltage Type
Metric	English	AC

CCP v 2.3.2

Environmental Input

Set Default Environmental Inputs

1029.6	Sun Radiation (W/m²)
35	Ambient Temp. (°C)
0.61	Wind (m/sec)
100	Elevation (m)
0.5	Solar Absorptivity
0.5	Emissivity
90	Wind Angle (deg.)
0	Azimuth of Line (NS=0, EW=90)
9	Latitude (neg = South)
February	Month
15	Day of Month
12	Time (24 hrs.)
Clear	Atmosphere

Load and Generation Cost Assumptions

10.0	Line Length (km)
132	Voltage (kV)
600	Peak Operating Amps
50%	Load Factor
29%	Loss Factor
137	Peak Power per Circuit (MW)
3	Phases/Circuit
50	Cost of Energy Generation ($/MWh)
0.200	CO_2 (kg/kWh)
0%	Load Increase/Year

ACSR Bear can just meet the increased 600 operating amps and 800 amp target with a weight increase of 66%. (1,213 vs 726)

3 ACSR Bear cannot be installed on current towers

Kumbotsu – Danagundi: ACSR OPTIONS

Conductor information

	Base Conductor	Conductor #1	Conductor #2
Type:	ACSR	ACSR	ACSR
Size (mm² Al - Code Word):	158 - WOLD	265 - BEAR	265 - BEAR
Initial Sag and Tension:		1	2
% RTS:	20.0%	12.0%	22.0%
Sag at Initial Sagging Temperature (m):	7.90	13.31	7.25
Initial Tension at Sagging Temperature (kN):	13.8	✓ 13.7	✗ 25.1
Sag/Tension at Above Stringing Temperature:		1b	2b
Sag at Peak Operating Amps – Temp(°C):	105	73	73
Sag (m):	10.64	14.50 ✗	8.92
Tension (kN):	10.3	12.6	20.4 ✗
Sag at Rated Operating Temperature – Temp(°C):	75	75	75
Sag (m):	9.61	14.56	9.01
Tension (kN):	11.4	12.5	20.2
Sag at Maximum Temperature – Temp(°C):	100	100	100
Sag (m):	10.50	15.03	9.92
Tension (kN):	10.4	12.1	18.4
Temperature at Maximum Allowable Sag – Max. Temp(°C):	86	29	100
Sag (m):	10.01	13.27	9.92
Tension (kN):	10.9	13.7	18
Ampacity Cells Turn Red if Max Capacity is not reached – Ampacity (A):	511		801
Wind / Ice or Cold Temperature Sag/Tension:			
Sag (m):	8.44	13.30	7.54
Tension (kN):	18.0	17.2	30.3

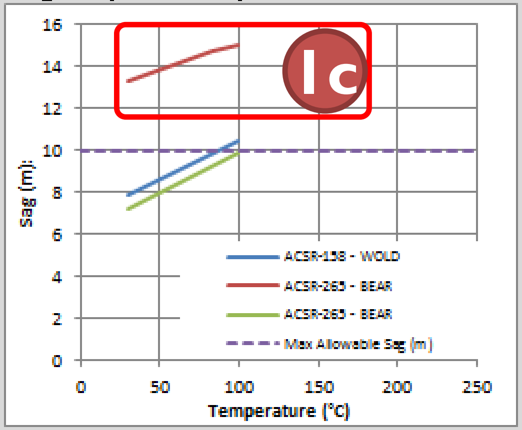
Units	Language	Voltage Type	
Metric	English	AC	CCP v 2.3.2

Environmental Input

Initial Sag and Tension:

350	Ruling Span (m)
30	Initial Sagging Temperature (°C)
10.0	Maximum Allowable Sag (m)

Sag Comparison Graph

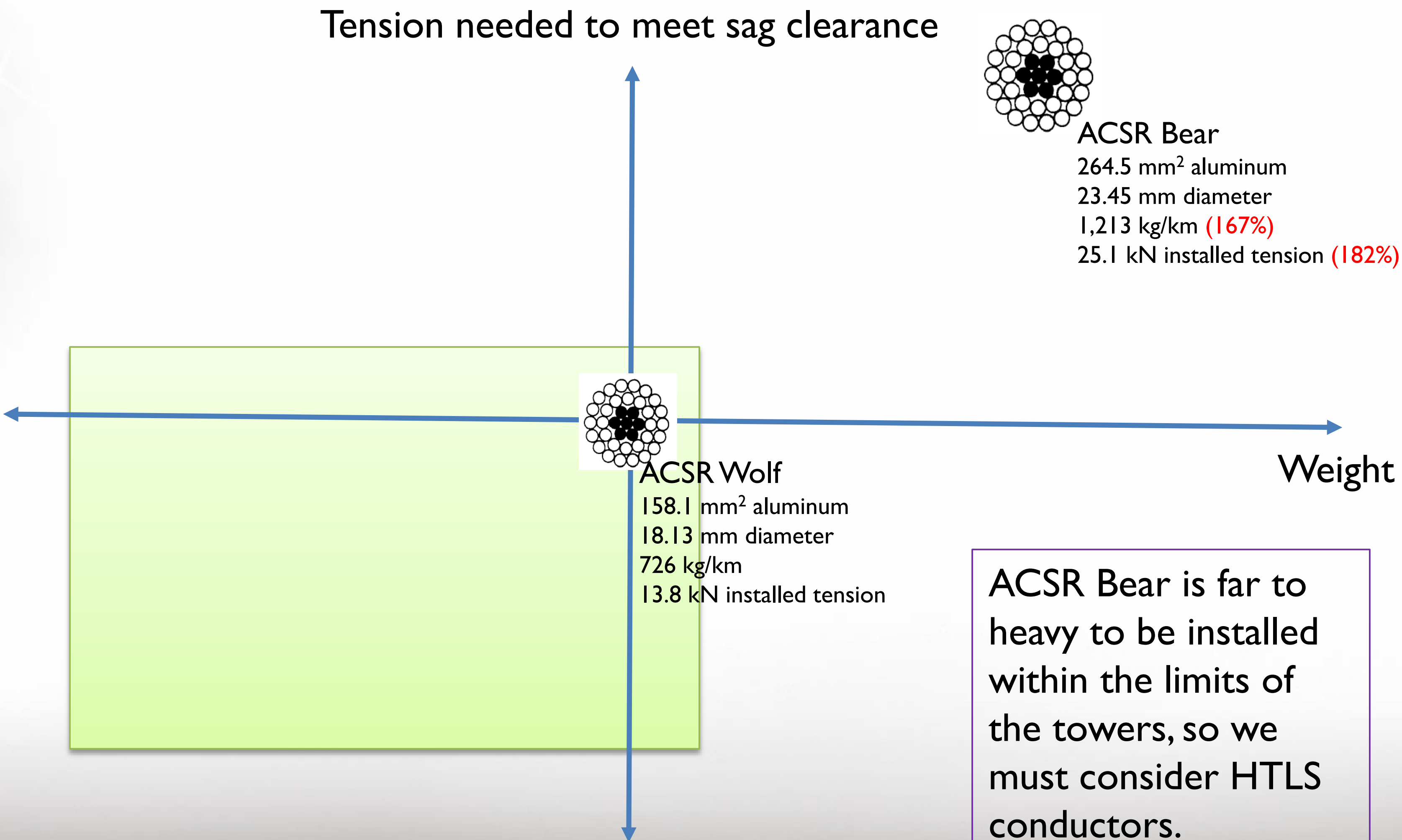


Wind / Ice Conditions

20	Temperature (°C)
90.0	Windspeed (km/hr)
0.00	Safety Factor (N/m)
0.00	Radial Ice Thickness (mm)
0.0	Ice Density (kg/m³)

ACSR Bear greatly exceed the constraint on installed tension and maximum allowable sag

Mapping conductors within limitations



ACSR Bear is far to heavy to be installed within the limits of the towers, so we must consider HTLS conductors.

4 ACSS conductors meet performance target

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Kumbotsu – Danagundi: ACSS/TW and ACSS round wire OPTIONS

Conductor information

		Base Conductor		Conductor #1		Conductor #2
Type:		ACSR		ACSS/TW		ACSS
Size (mm² Al - Code Word):		158 - WOLD		170 - ORIOLE		170 - ORIOLE
Aluminum Area (mm²):		158.1		170.5		170.5
Diameter (mm):		18.130		17.602		18.821
Rated Strength (kN):		69		66		66
Weight (kg/km):		726.0		783.2		783.2
DC Resistance at 20°C (ohms/km):		0.17875		0.16010		0.16010
AC Resistance at 25°C (ohms/km):		0.18285		0.16293		0.16375
AC Resistance at 75°C (ohms/km):		0.21881		0.19580		0.19678
Conductors per phase:		1		1		1
Circuits:		1		1		1
Ampacity (A) at Temperature (°C):	70	416	70	437	70	443
Ampacity (A) at Rated Operating Temp (°C):	75	449	200	915	200	932
Ampacity (A) at Maximum Temp (°C):	100	577	250	1,023	250	1,043

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Line Loss (Based on Inputted Peaking Operating Amps Value)

	Base Conductor	Conductor #1	Conductor #2
Steady-State Temperature (°C) at Peak Ampacity:	105	99	97
Resistance at Peak Operating Amps (ohm/km):	0.24074	0.21159	0.21129
First Year Line Losses (MWh):	6,548	5,755	5,747
ACSR 158 - WOLD - Reduces First Year CO_2 Generated by (MT):		-72	-73
ACSR 158 - WOLD - Reduces First Year Line Losses by (MWh):		-793	-801
ACSR 158 - WOLD - Reduces First Year Line Losses by (%):		-14%	-14%
ACSR 158 - WOLD - Reduces First Year Line Losses by ($/Year):		-39,635	-40,048
ACSR 158 - WOLD - Line Loss Savings per meter of Conductor ($/m):		-1.32	-1.33
ACSR 158 - WOLD - Reduces 30 year line loss by ($):		-1,189,054	-1,201,428
ACSR 158 - WOLD - Reduces 30 year CO_2 generation by (MT):		-4,756	-4,806

Units	Language	Voltage Type
Metric	English	AC

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Environmental Input

Set Default Environmental Inputs

1029.6	Sun Radiation (W/m²)
35	Ambient Temp. (°C)
0.61	Wind (m/sec)
100	Elevation (m)
0.5	Solar Absorptivity
0.5	Emissivity
90	Wind Angle (deg.)
0	Azimuth of Line (NS=0, EW=90)
9	Latitude (neg = South)
February	Month
15	Day of Month
12	Time (24 hrs.)
Clear	Atmosphere

Load and Generation Cost Assumptions

10.0	Line Length (km)
132	Voltage (kV)
600	Peak Operating Amps
50%	Load Factor
29%	Loss Factor
137	Peak Power per Circuit (MW)
3	Phases/Circuit
50	Cost of Energy Generation ($/MWh)
0.200	CO_2 (kg/kWh)
0%	Load Increase/Year

ACSS/TW Oriole and ACSS Oriole meet capacity requirements with only slightly higher weight than ACSR Wolf

4 Sag/tension limits ACSS/TW to 600 amp target

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Kumbotsu – Danagundi: ACSS/TW and ACSS round wire OPTIONS

Conductor information		Base Conductor	Conductor #1	Conductor #2
	Type:	ACSR	ACSS/TW	ACSS
	Size (mm² Al - Code Word):	158 - WOLD	170 - ORIOLE	170 - ORIOLE
Initial Sag and Tension:				
	% RTS:	20.0%	24.0%	22.0%
	Sag at Initial Sagging Temperature (m):	7.90	7.45	8.13
	Initial Tension at Sagging Temperature (kN):	13.8	15.8	14.5
Sag/Tension at Above Stringing Temperature:				
Sag at Peak Operating Amps	Temp(°C):	105	99	97
	Sag (m):	10.64	10.02	10.55
	Tension (kN):	10.3	11.7	11.2
Sag at Rated Operating Temperature	Temp(°C):	75	200	200
	Sag (m):	9.61	11.94	12.51
	Tension (kN):	11.4	9.9	9.4
Sag at Maximum Temperature	Temp(°C):	100	250	250
	Sag (m):	10.50	12.84	13.39
	Tension (kN):	10.4	9.2	8.8
Temperature at Maximum Allowable Sag	Max. Temp(°C):	86	99	82
	Sag (m):	10.01	10.02	10.04
Ampacity Cells Turn Red if Max Capacity is not reached	Tension (kN):	10.9	11.7	12
	Ampacity (A):	511	600	521
Wind / Ice or Cold Temperature Sag/Tension:				
	Sag (m):	8.44	8.19	8.89
	Tension (kN):	18.0	19.1	18.2

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Units	Language	Voltage Type
Metric	English	AC

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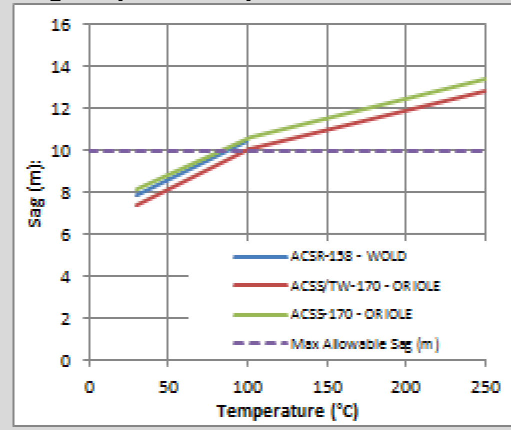
Environmental Input

Initial Sag and Tension:

350	Ruling Span (m)
30	Initial Sagging Temperature (°C)
10.0	Maximum Allowable Sag (m)

Sag Comparison Graph

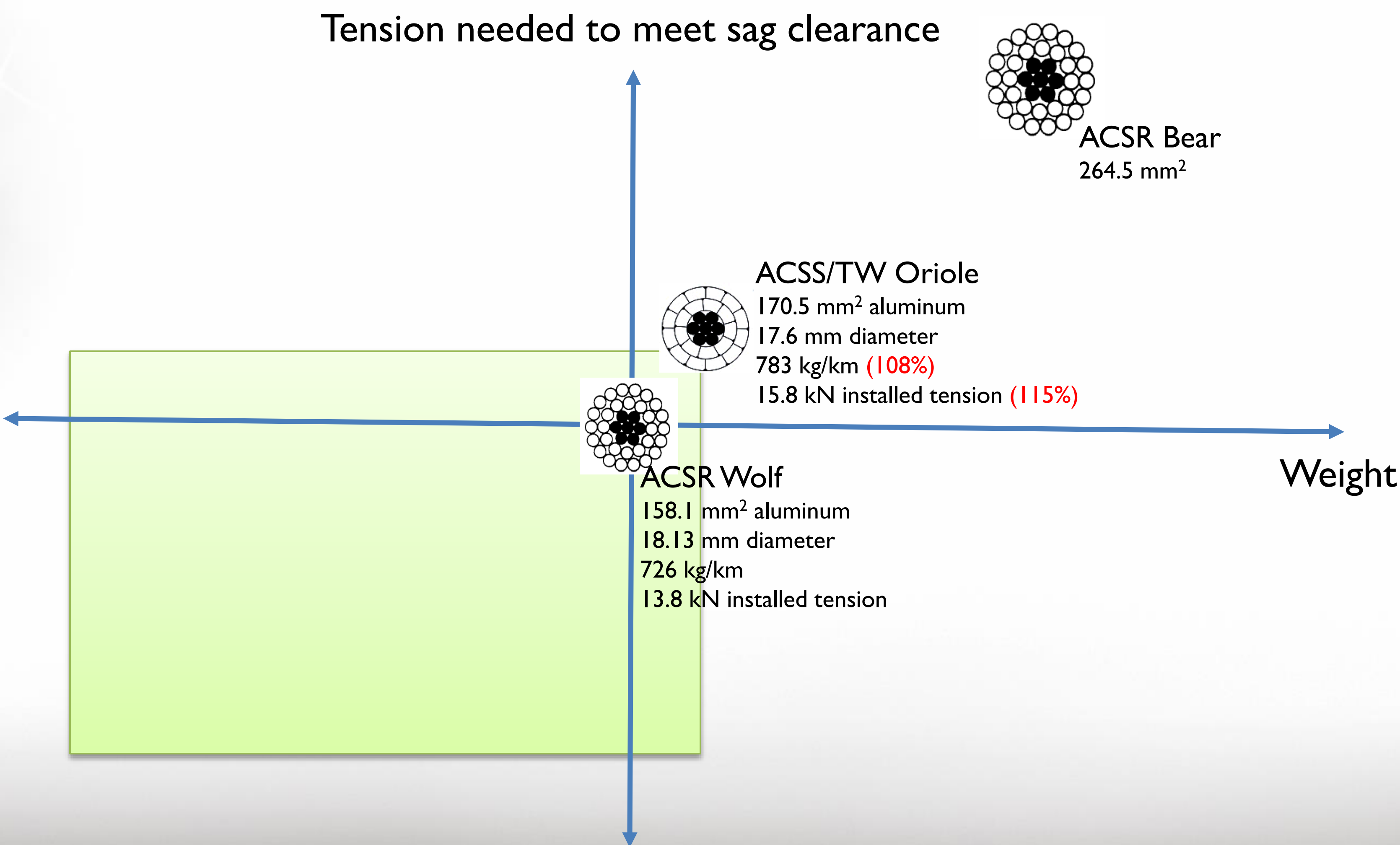


Wind / Ice Conditions

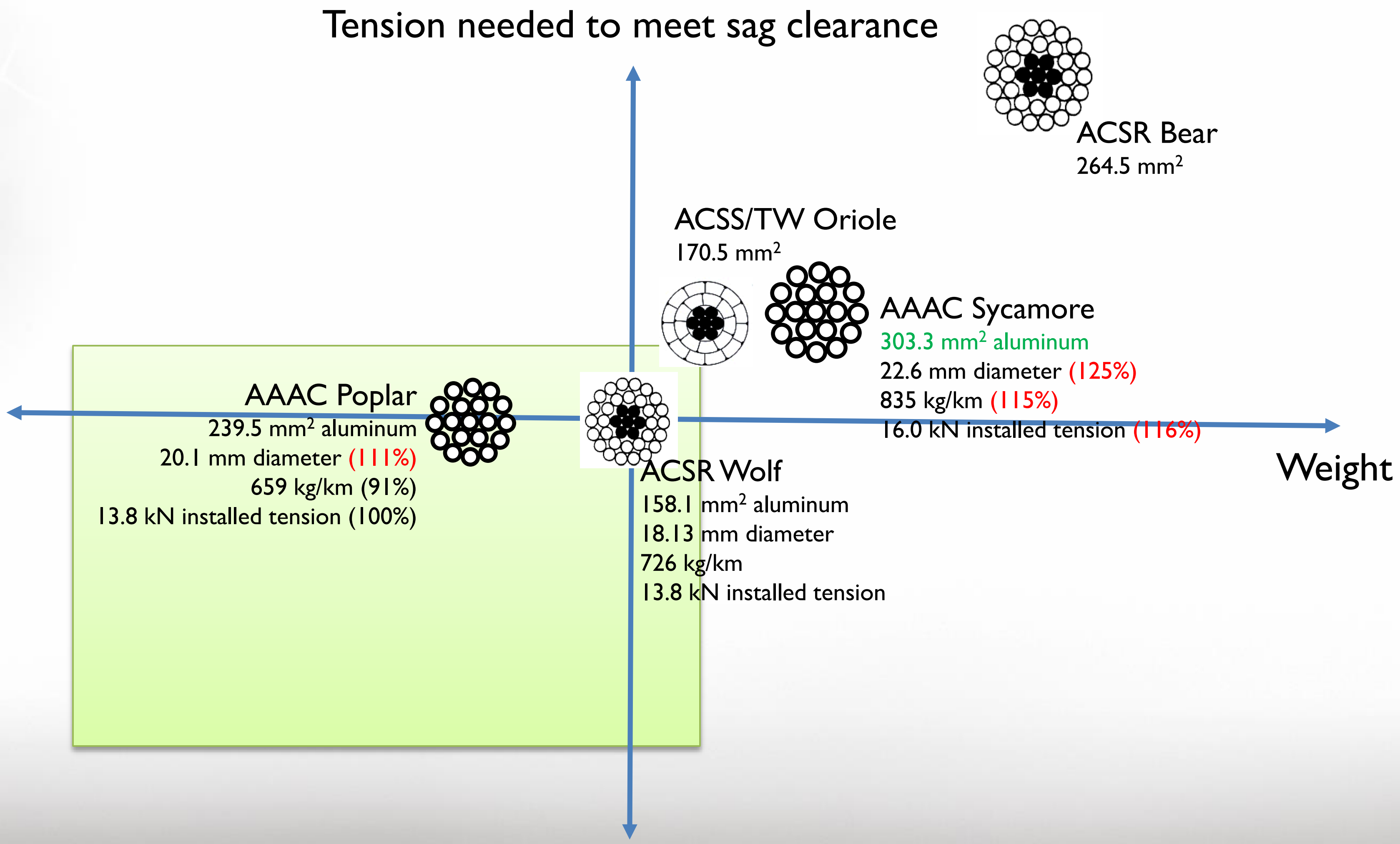
20	Temperature (°C)
90.0	Windspeed (km/hr)
0.00	Safety Factor (N/m)
0.00	Radial Ice Thickness (mm)
0.0	Ice Density (kg/m³)

ACSS/TW Oriole and ACSS Oriole are sag limited, even when the installed tension exceeds the criteria by 15%

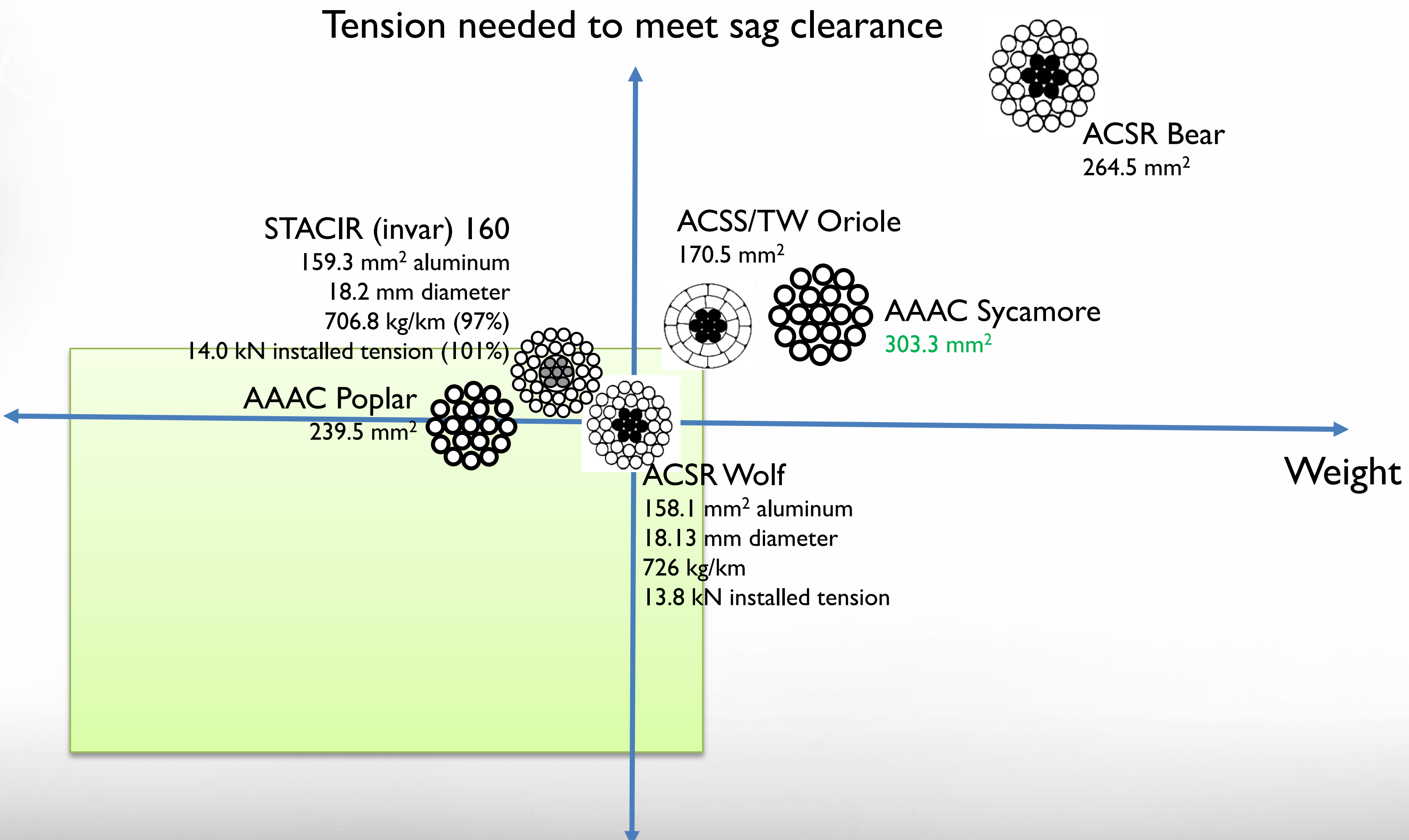
Mapping conductors within limitations



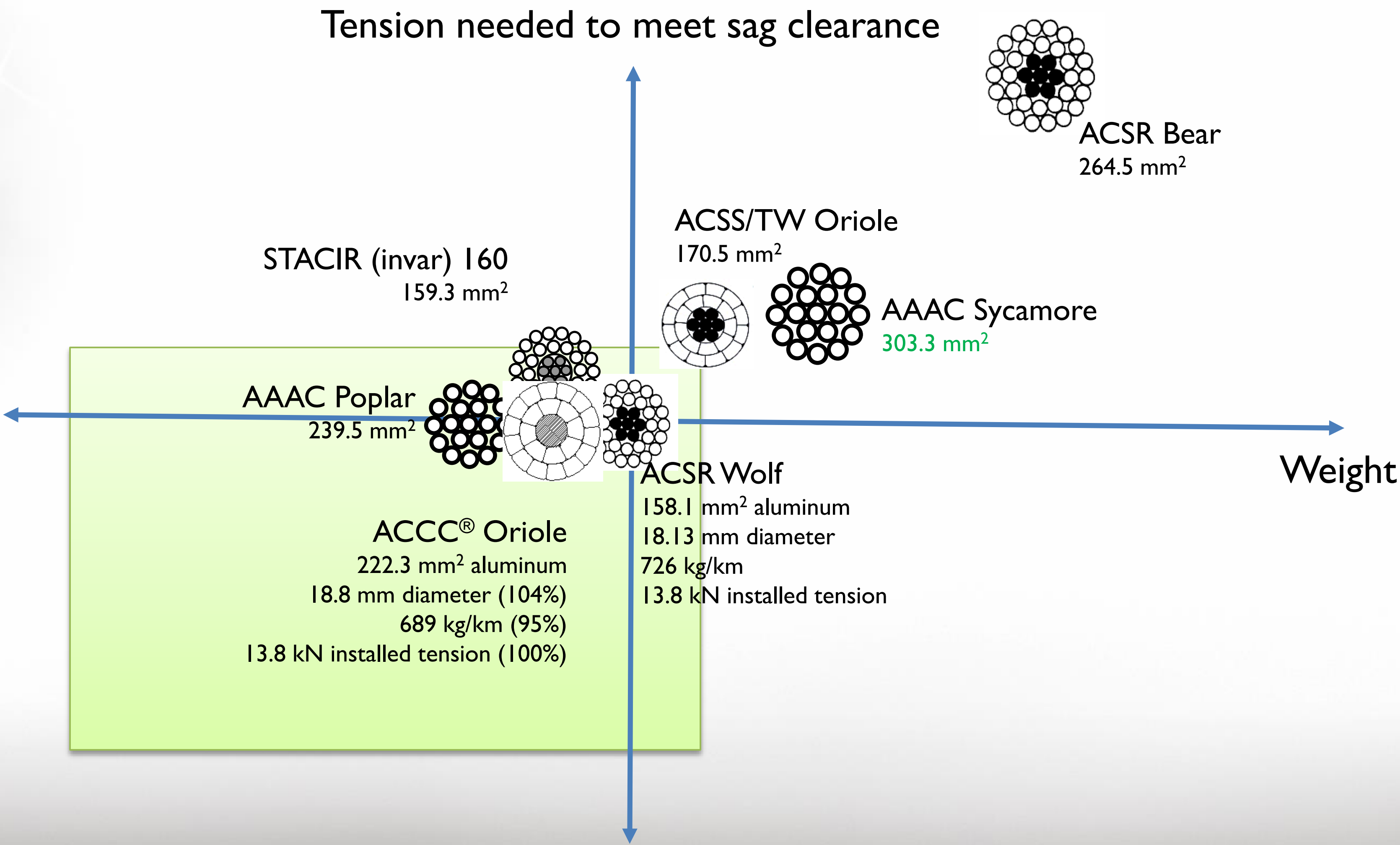
Mapping conductors within limitations



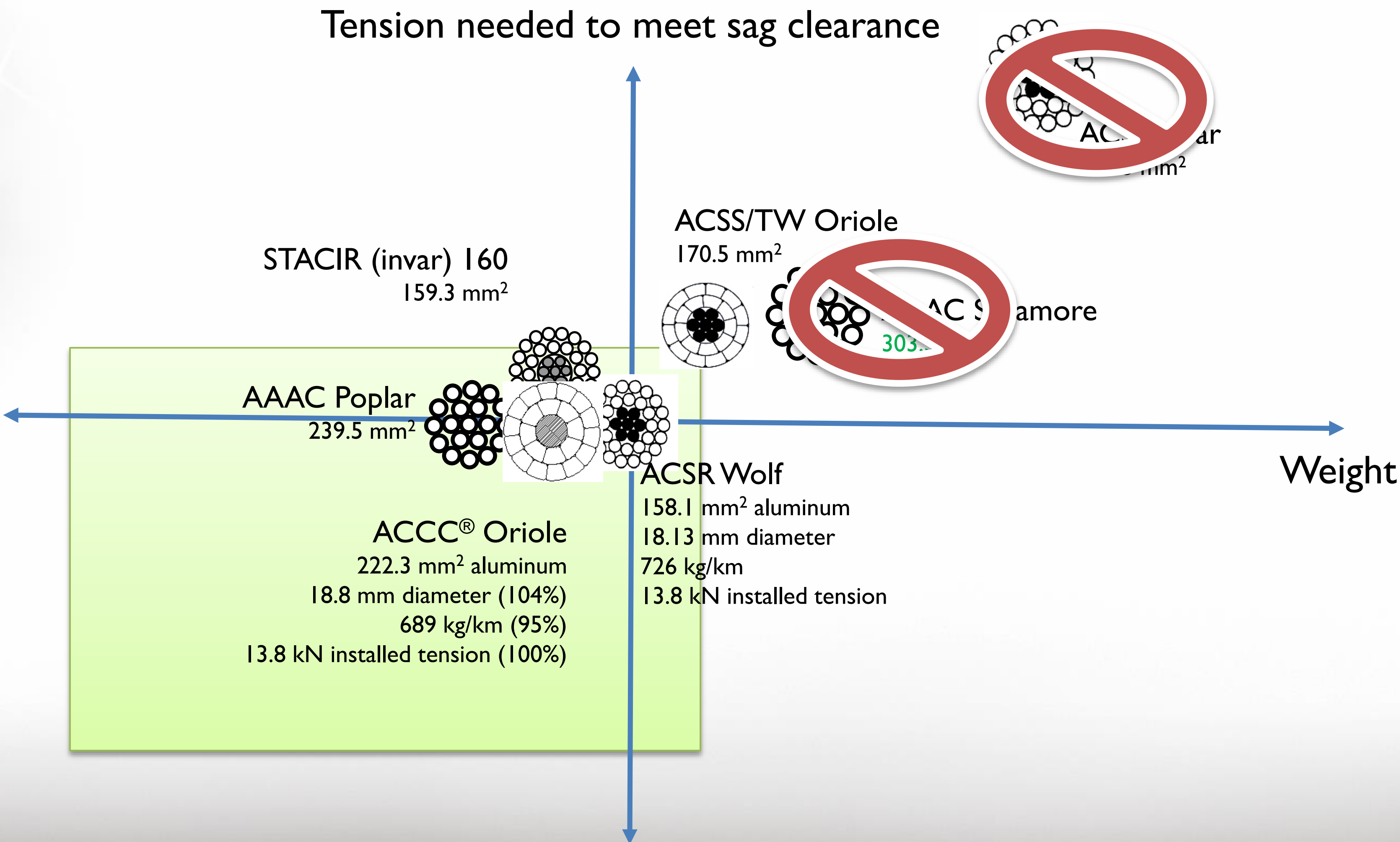
Mapping conductors within limitations



Mapping conductors within limitations

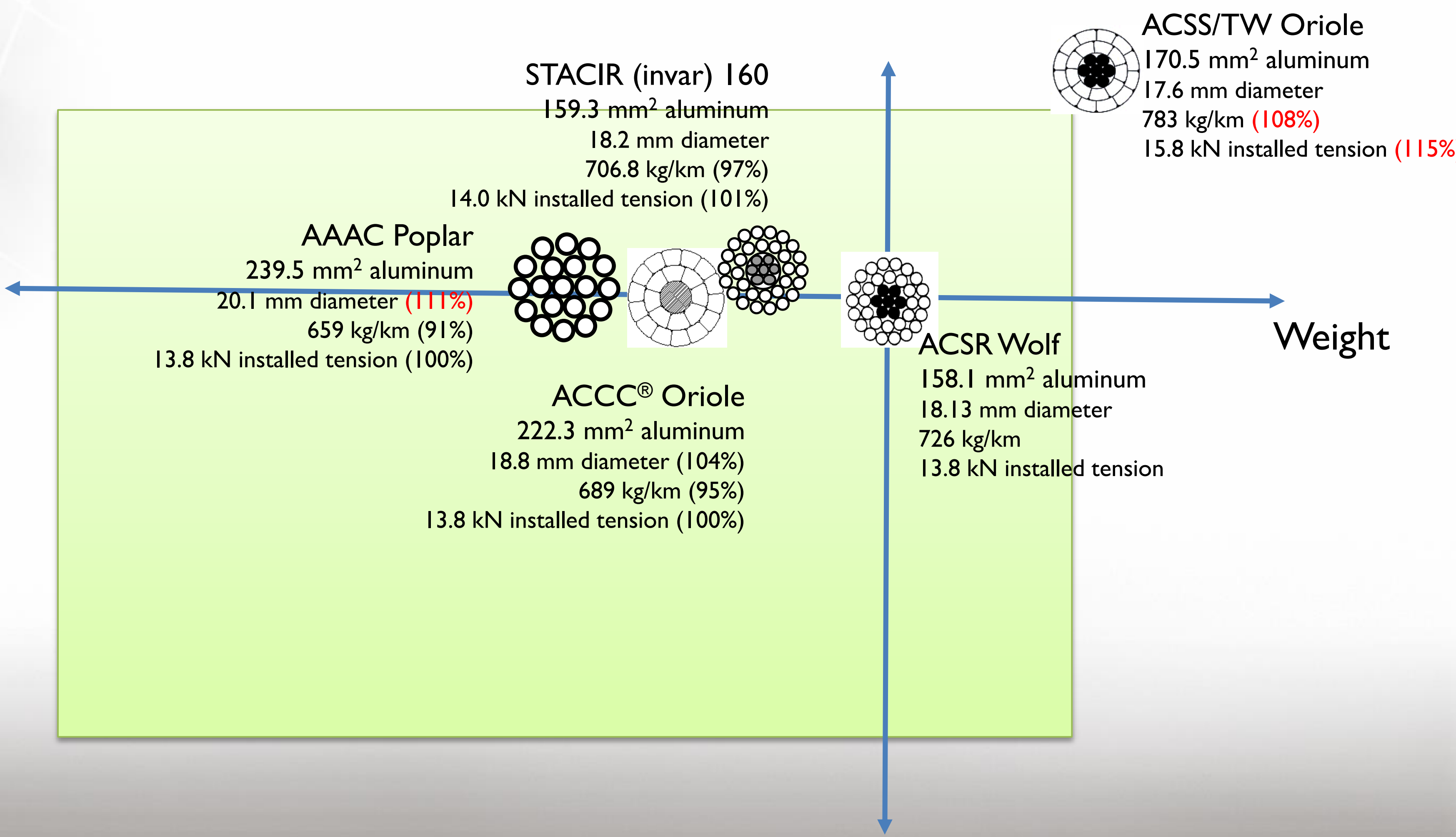


Mapping conductors within limitations



Mapping conductors within limitations

Tension needed to meet sag clearance



Relative conductivity CO2 generation

	ACSR	STACIR	ACSS/TW	AAAC	ACCC
Aluminum Area mm2	158.1	159.3	170.5	239.5	222.3
%IACS	61.20%	60%	63%	52.50%	63%
Relative conductivity	97	96	107	126	140
Resistance at 600 amps (ohm/km)	0.2407	0.2259	0.2116	0.1739	0.1578
Annual line losses (MWh)	6,548	6,146	5,755	4,713	4,293
CO2 Generated (MT)	1,310	1,229	1,151	943	859
Reduced CO2 versus ACSR (MT)	0	80	159	367	451
Reduced CO2 per KM (MT)	0	8	16	37	45
% Reduction CO2 Generation	0%	6%	12%	28%	34%

- With all other design conditions the same on this short (10km) 132kv line, conductor choices can reduce CO2 generation by 6 to 34%, versus an overloaded ACSR Wolf.

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Bigger lines equals bigger results

120 Circuit Mile AEP Project Example

345 kV Line – Replace ACSR with ACCC

- Increased line capacity by 75% with 625 amp emergency reserve
- Reduced line losses by 30%
- Line loss reduction saves 141,580 MWh / year (=$7.1M @ $50/MWh)

- **Emission reductions saves 57,798 Metric Tons CO2 / year**
  - This equates to removing over 12,000 cars from the road
  - Line loss reduction also frees up over 16 MW of generation

Notes:
Double bundled conductor. Load factor Assumption = 34%
US National Average CO2 = 1.372# / kWh. (1 car = 4.75 MT CO2 / year)

Regional Impact in South East Asia

- 18 million MT reduction of CO2 every year

Country	MWh/Year*	CO^2 MMT**	5% losses (MWh)	30% saving	CO^2 reduction
Indonesia	216,200,000	477 MMT	10,810,000	3,243,000	7.2 MMT
Thailand	164,800,000	258 MMT	8,240,000	2,472,000	3.9 MMT
Malaysia	131,600,000	216 MMT	6,580,000	1,974,000	3.2 MMT
Vietnam	157,480,000	146 MMT	7,874,000	2,362,200	2.2 MMT
Philippines	76,000,000	87 MMT	3,800,000	1,140,000	1.3 MMT
Myanmar	7,144,000	13 MMT	357,200	107,160	0.2 MMT
Cambodia	991,000	5 MMT	49,550	14,865	0.1 MMT
Laos	12,240,000	3 MMT	612,000	183,600	0.05 MMT
TOTAL	**766,455,000**	**1,205 MMT**	**38,322,750**	**11,496,825**	**18 MMT**

* Source: Worldbook: Statistical Review of World Energy 2014, and EIA – International Energy Statistics 2014
** Source: Enerdata 2013

1-2% lower GHG generation

- Using or changing to efficient conductors reduces line losses by 1 – 2 % and CO_2 generation by the same amount.
- Renewable generation benefits through 1-2% more delivered power.
- Better efficiency and better return on capital projects go hand in hand (it is not double counting), so efficiency also generates more profitability for minimal capital cost increase.

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