

NATURAL GAS MARKETS & LED IN SCHOOLS

CASDEM Meeting
November 17, 2022

AGENDA

- 10:00-10:30** **Meeting Kick-off - *Welcome and Introductions***
- 10:30-10:55** **Natural Gas Market Update - *UET***
- 11:00-11:45** **The State of LED in Schools - *McBride Lighting & Electrical Services***
- 11:45-12:30** **CASDEM Strategy & Business**

WELCOME AND INTRODUCTIONS

Name

Role and organization

Icebreaker: Have you submitted all benchmarking data for your >50,000 sq ft buildings?

NATURAL GAS MARKET UPDATE

Karen Simpson
UET



United Energy Trading, LLC

Colorado Association of School District Energy Managers

November 17, 2022



NYMEX pricing

1

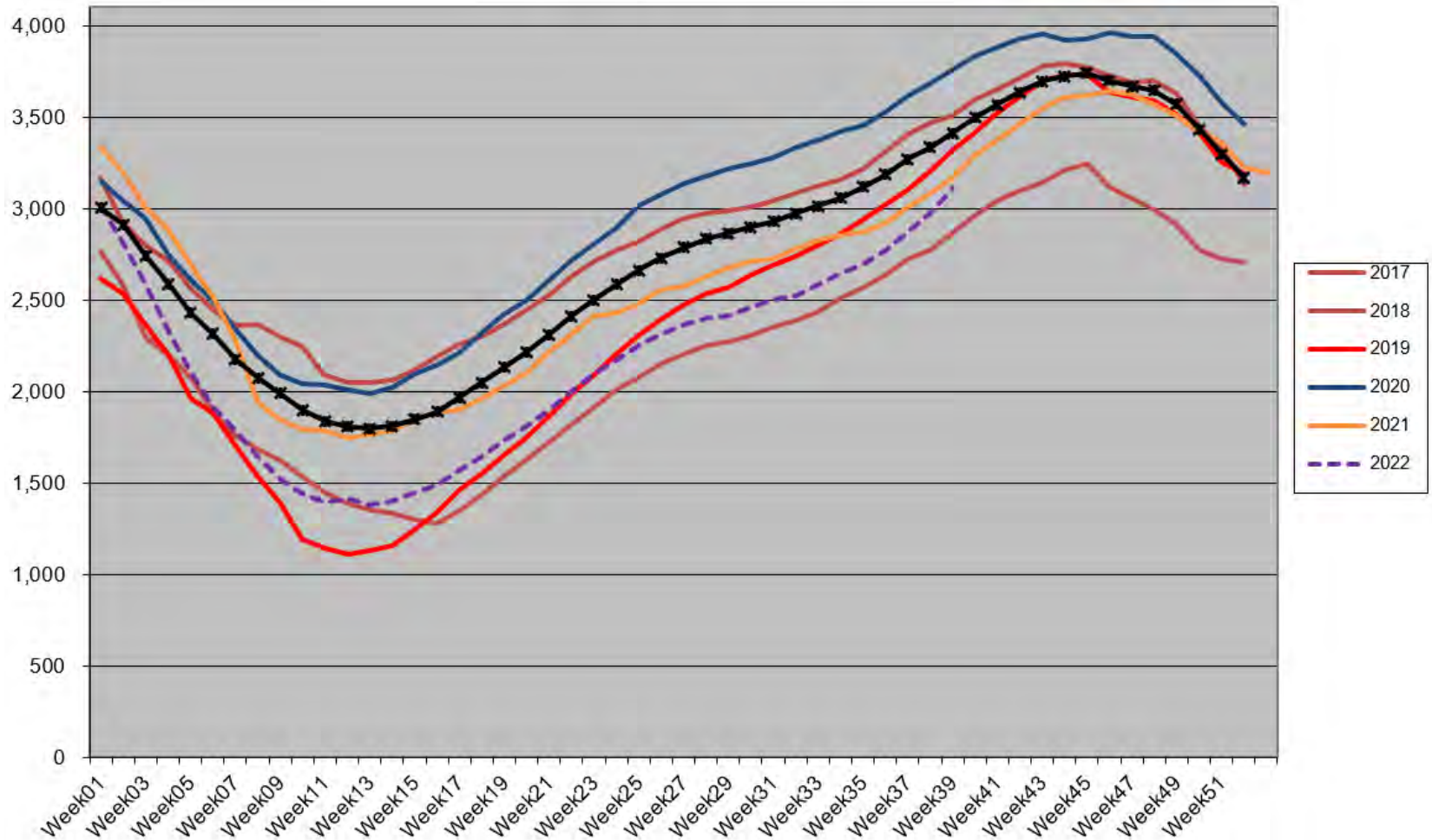


Henry Hub Prices





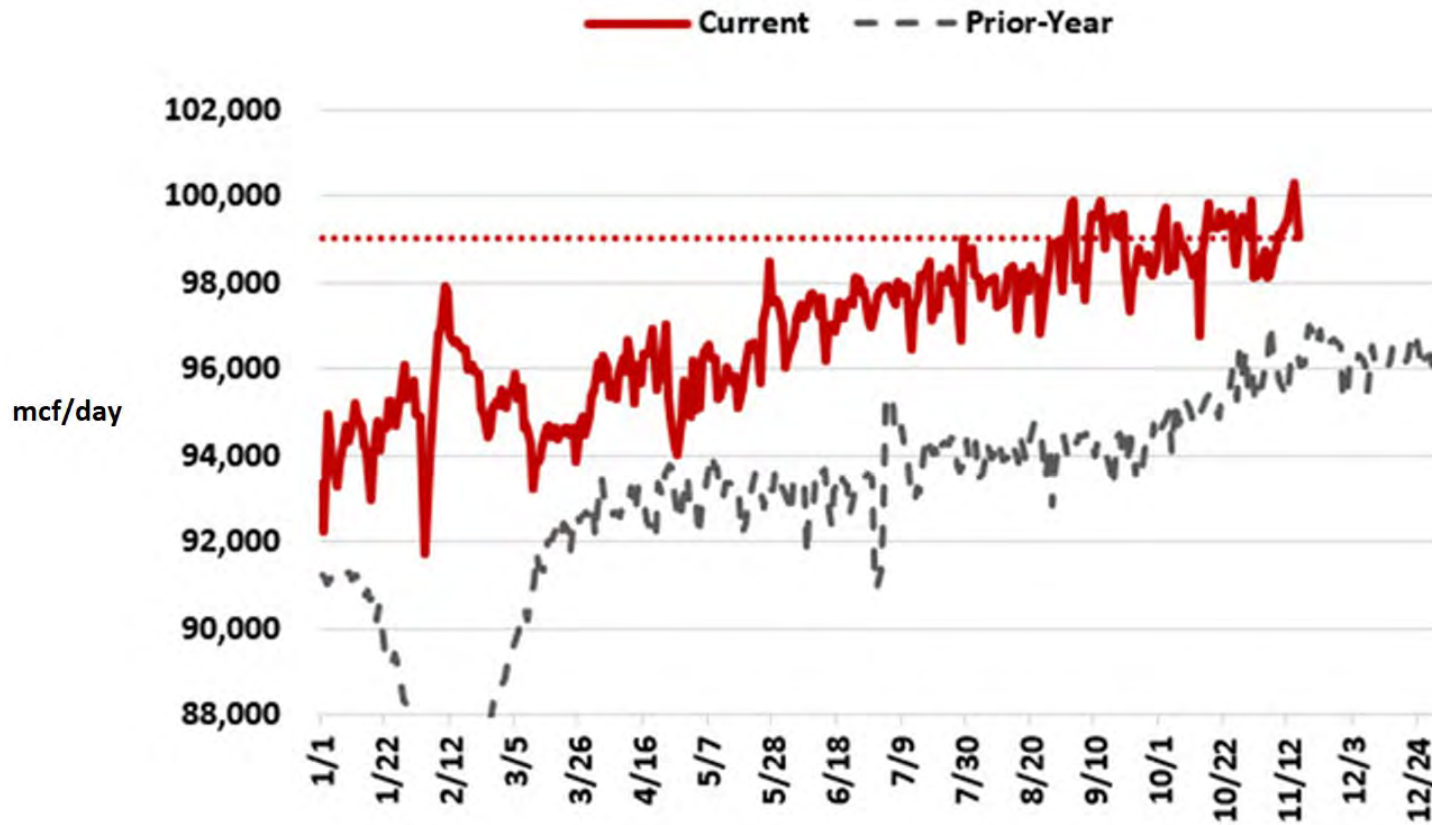
EIA - Total Storage Level (BCF)





Production

Lower 48 Gas Production





CIG Prices

**CIG GAS INDEX PRICES
2016 THROUGH CURRENT**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
2016	\$1.90	\$1.99	\$1.49	\$1.51	\$1.74	\$1.75	\$2.44	\$2.43	\$2.53	\$2.65	\$2.54	\$2.77	\$2.15
2017	\$3.63	\$3.12	\$2.28	\$2.63	\$2.59	\$2.76	\$2.58	\$2.57	\$2.56	\$2.48	\$2.53	\$2.66	\$2.70
2018	\$2.40	\$2.73	\$2.13	\$1.74	\$1.80	\$1.96	\$2.08	\$2.23	\$2.22	\$2.04	\$3.03	\$4.10	\$2.37
2019	\$3.54	\$2.85	\$2.45	\$2.25	\$1.75	\$1.86	\$1.61	\$1.76	\$1.65	\$1.79	\$1.94	\$2.29	\$2.15
2020	\$1.86	\$1.64	\$1.45	\$1.28	\$1.53	\$1.46	\$1.49	\$1.58	\$2.20	\$1.93	\$2.77	\$2.41	\$1.80
2021	\$2.42	\$2.40	\$2.86	\$2.24	\$2.56	\$2.67	\$3.16	\$3.78	\$3.67	\$4.79	\$5.57	\$4.91	\$3.42
2022	\$5.39	\$4.77	\$4.35	\$4.84	\$6.13	\$8.42	\$5.84	\$8.26	\$8.54	\$5.23	\$4.88		\$6.06



PSCO

2



Public Service Company of Colorado
Natural Gas Rates Summary
Effective November 1, 2022

Schedule	Charge Type	Charge Amount	Gas Energy Assistance Charge (GEAC)	General Rate Schedule Adjustment (GRSA) 1.68%	General Rate Schedule Adjustment - P (GRSA-P)	GAS RATE ADJUSTMENTS AS APPLICABLE			Total Monthly Rate
						Demand Side Management Cost Adjustment	Extraordinary Gas Cost Recovery Rider	Gas Cost Adjustment	
						(DSMCA - RG _s) 5.08%	(EGCRR)	(GCA)	
						2.66%			
Residential (R)	Service and Facility per Month	\$10.21	\$0.75	1.68%	-0.71%	5.08%			\$11.58
	Usage Charge per Therm	\$0.31717		1.68%	-0.71%	5.08%	\$0.07221	\$1.0092	\$14.178
Small Commercial (CSG)	Service and Facility per Month	\$45.88	\$0.75	1.68%	-0.86%	2.66%			\$48.23
	Usage Charge per Therm	\$0.25077		1.68%	-0.86%	2.66%	\$0.07221	\$1.0041	\$13.358
Large Commercial (CLG)	Service and Facility per Month	\$139.15	\$0.75	1.68%	-1.45%	2.66%			\$143.92
	Usage Charge per Dekatherm	\$0.4977		1.68%	-1.45%	2.66%	\$0.72213	\$9.9960	\$11.230
	Capacity Charge per Dekatherm	\$15.00		1.68%	-1.45%	2.66%			\$15.434
Interruptible Sales (IG)	Service and Facility per Month	\$156.86	\$0.75	1.68%	-5.82%	2.66%			\$155.29
	Usage Charge per Dekatherm	\$1.0497		1.68%	-5.82%	2.66%	\$0.72213	\$9.8810	\$11.637
	On-Peak Demand Charge per Dekatherm	\$15.00		1.68%	-5.82%	2.66%		\$1.5860	\$16.364
	Unauthorized Overrun Charge	(2)		1.68%	-5.82%	2.66%			(\$1.970)
Small Firm Transportation (TFS)	Service and Facility per Month	\$70.13		1.68%	-1.28%				\$70.41
	Transportation Charge - Standard per Dekatherm	\$2.5077		1.68%	-1.28%			\$0.042	\$2.560
	Firm Supply Reservation							\$1.586	\$1.586
	Backup Supply per Dekatherm (Transportation)	\$2.5077		1.68%	-1.28%			(1)	(1)
	Unauthorized Overrun Charge - Sales Standard per Dekatherm	(2)		1.68%	-1.28%				(2)
	Unauthorized Overrun Charge - Sales Minimum per Dekatherm	\$2.5077		1.68%	-1.28%				\$2.518
Large Firm Transportation (TFL)	Service and Facility per Month	\$163.40		1.68%	-1.85%				\$163.12
	Firm Capacity Reservation Charge - Standard per Dekatherm	\$15.00		1.68%	-1.85%				\$14.975
	Transportation Charge - Standard per Dekatherm	\$0.4977		1.68%	-1.85%			\$0.042	\$0.539
	Firm Supply Reservation							\$1.586	\$1.586
	Backup Supply per Dekatherm (Transportation)	\$0.4977		1.68%	-1.85%			(1)	(1)
	Authorized Overrun per Dekatherm (Sales)	\$1.0497		1.68%	-1.85%			\$0.042	\$1.090
	Unauthorized Overrun Charge - Sales Standard per Dekatherm	(2)		1.68%	-1.85%				(2)
	Unauthorized Overrun Charge - Sales Minimum per Dekatherm	\$0.4977		1.68%	-1.85%				\$0.497
Interruptible Transportation (TI)	Service and Facility per Month	\$181.11		1.68%	-5.75%				\$173.74
	Transportation Charge - Standard per Dekatherm	\$1.0497		1.68%	-5.75%			\$0.042	\$1.049
	On-Peak Demand - per Dekatherm	\$15.00		1.68%	-5.75%			\$1.586	\$15.976
	Unauthorized Overrun Charge - Sales Standard per Dekatherm	(2)							(2)
	Unauthorized Overrun Charge - Sales Minimum per Dekatherm	\$1.0497		1.68%	-5.75%				\$1.007

(1) The Gas Cost Adjustment applicable to this rate is subject to monthly revision as provided for on Sheet No. 50H.

(2) See Tariff

► Small Commercial Usage Charge per Dekatherm (Total Monthly Rate) = \$13.358

► Large Commercial Usage Charge per Dekatherm (Total Monthly Rate) = \$11.230



Rate Schedule

Rates effective Nov 1, 2022					
Firm Rates		DSMCA + GRSA + GRSA-P	Dth Rate Effective 10/15/2022		
	Base Rate	Adjustment Percentage	* EGCRR	GCA	(Rounded) Total Rate:
Commercial Sales - SMALL GAS SERVICE:					
CSG - Service & Facility Charge per Meter	\$45.88	3.4800%		\$0.000	\$48.23
CSG - Usage per Dth	\$2.5080	3.4800%	\$0.72213	(Note 1)	
TFS Transportation Rates:					
TFS Service & Facility Charge per Meter	\$70.13	0.4000%		\$0.000	\$70.41
Transportation charges per Dth:					
Standard	\$2.5080	0.4000%		\$0.04200	\$2.560
Unauthorized Overrun Penalty (Per Dth)					
Maximum	(Note 3)	0.4000%		\$0.000	
TFS Backup Sales Service:					
Firm Supply Reservation (per Dth of Backup Quantity):	\$0.0000	0.4000%		\$1.5860	\$1.586
Back up supply (per Dth):	\$2.5080	0.4000%		(Note 2)	
Commercial Sales - LARGE GAS SERVICE:					
CLG - Service & Facility Charge per Meter	\$139.15	2.8900%		\$0.000	\$143.92
CLG - Capacity Charge per MDQ in Dth	\$15.00	2.8900%		\$0.000	\$15.434
CLG - Usage per Dth	\$0.4977	2.8900%	\$0.72213	(Note 1)	
TFL Transportation Rates:					
TFL Service & Facility Charge per Meter	\$163.40	-0.1700%		\$0.000	\$163.12
Firm Capacity Reservation Charge (Per MDQ in Dth):					
Standard	\$15.00	-0.1700%		\$0.000	\$14.975
Transportation Charge per Dth:					
Standard	\$0.4977	-0.1700%		\$0.04200	\$0.539
Authorized Overrun (Per Dth)	\$1.0497	-0.1700%		\$0.04200	\$1.090
Unauthorized Overrun Penalty (Per Dth)					
Maximum	(Note 3)	-0.1700%		\$0.000	
TFL Backup Sales Service:					
Firm Supply Reservation (per Dth of Backup Quantity):	\$0.00	-0.1700%		\$1.5860	\$1.586
Back up supply (per Dth):	\$0.4977	-0.1700%		(Note 2)	



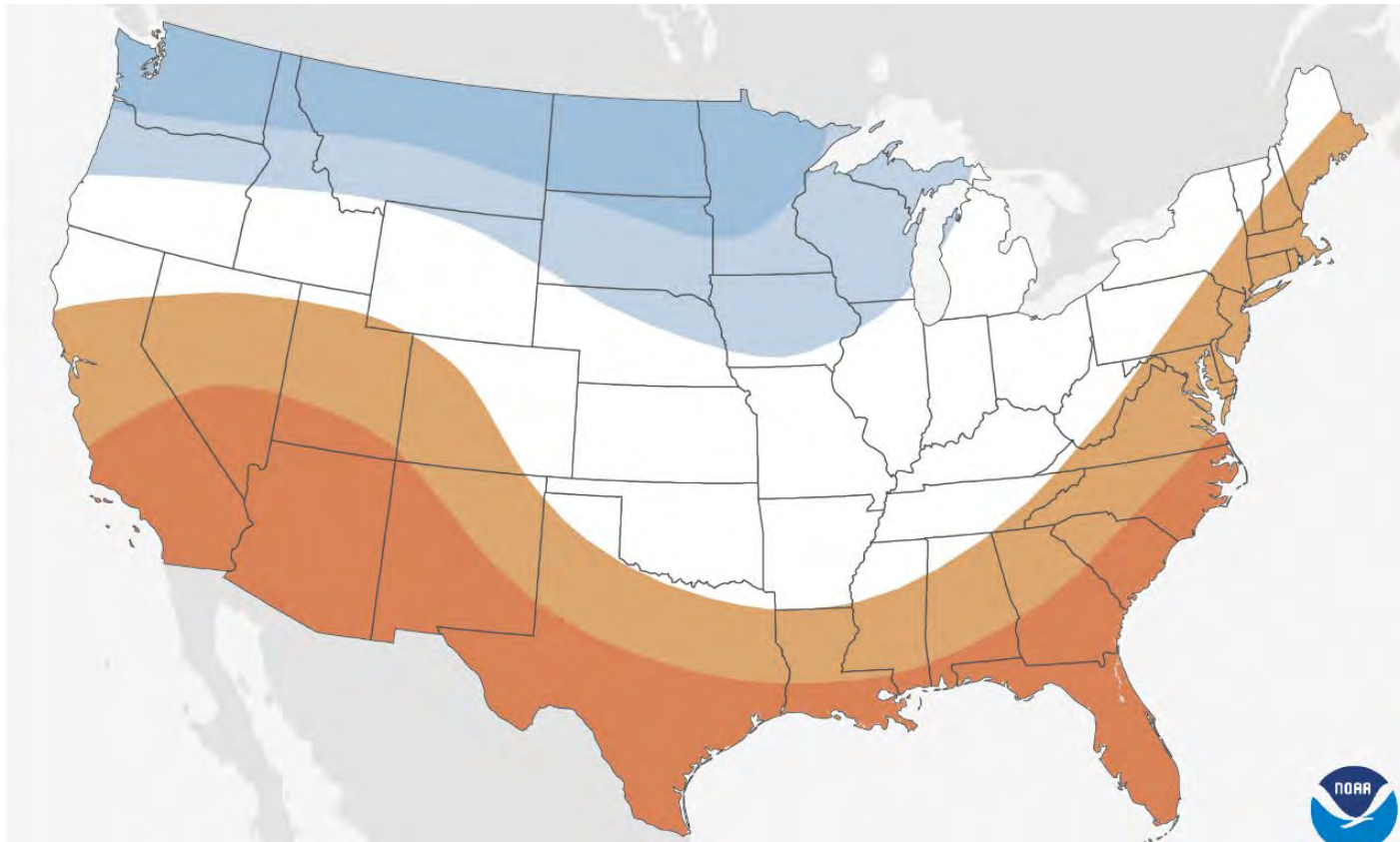
Winter Weather Forecast

3



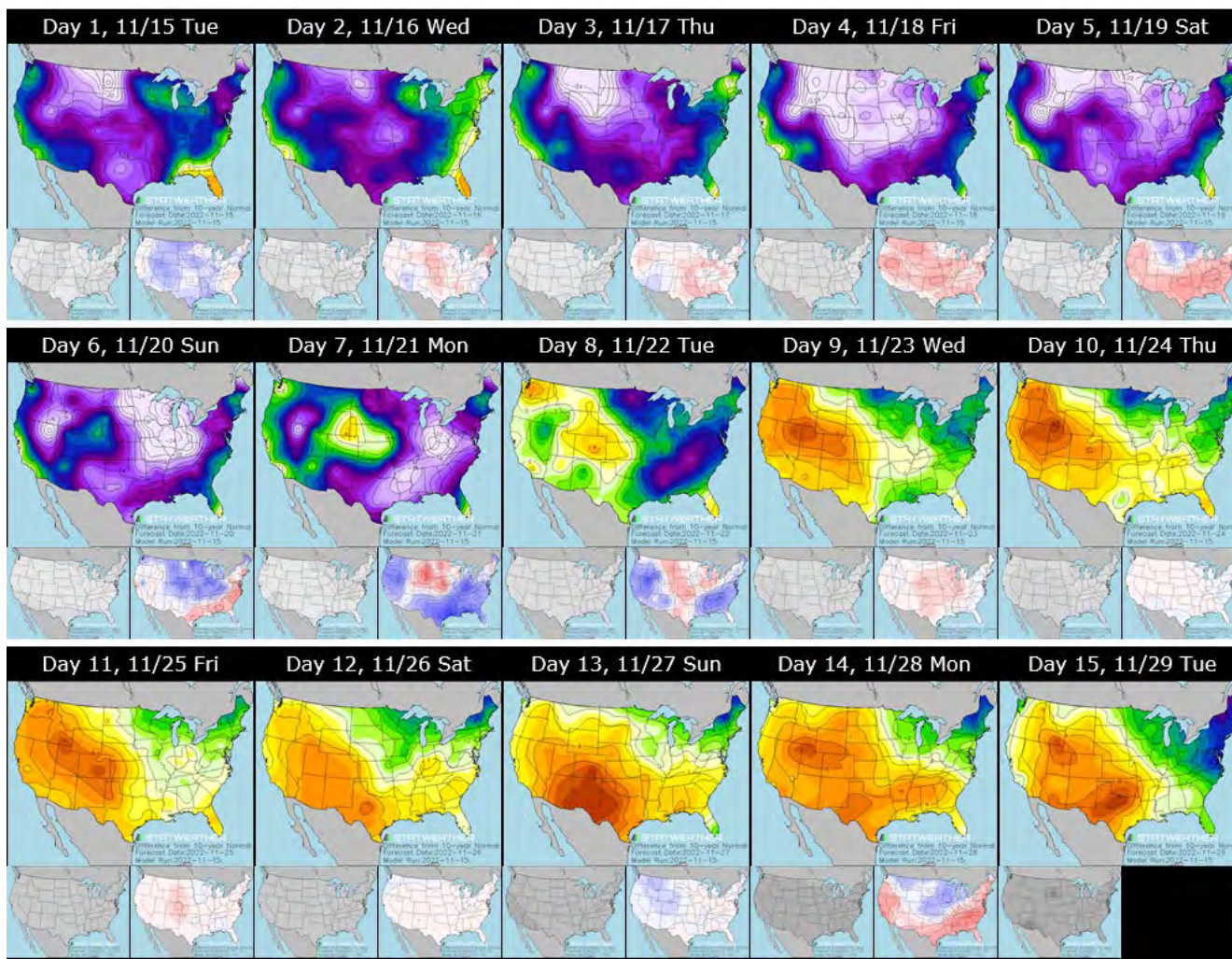
Winter Weather Forecast

- ▶ 3rd consecutive La Niña – warmer temperatures for Southwest and along Gulf Coast and eastern seaboard





STATWEATHER





Renewables

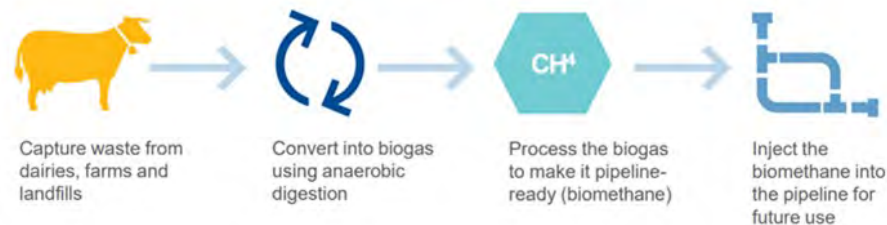
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RNG

- **Renewable Natural Gas (RNG)** is a pipeline-quality gas that is fully interchangeable with conventional natural gas and thus can be used in natural gas vehicles.
- RNG is created from inedible food waste, manure, municipal solid waste, and wastewater and is broken down by a naturally occurring process called anaerobic digestion and then repurposed into fuel for everyday use.
 - RNG is essentially biogas that has been processed to purity standards.
- Because RNG captures emissions from society's waste streams and redeems its energy value, it has the lowest life cycle carbon intensity (CI) of any clean energy source available today. RNG helps decarbonize energy and combats climate change.

The basics of Renewable Natural Gas



Waste Types Used to Make RNG

Municipal Solid Waste



Sewage Sludge



Yard and Crop Wastes



Food and Food Processing Wastes



Manure



Landfills

Biogas made from organic sources through anaerobic processes contains 45–65% methane.

Biogas is treated to remove moisture, particulates, contaminants and other gases (CO_2 , O_2 , N_2 and VOCs); this increases the methane content to 90% or greater—typically 96–98% for pipeline injection.

The resulting product is **renewable natural gas (RNG)**.

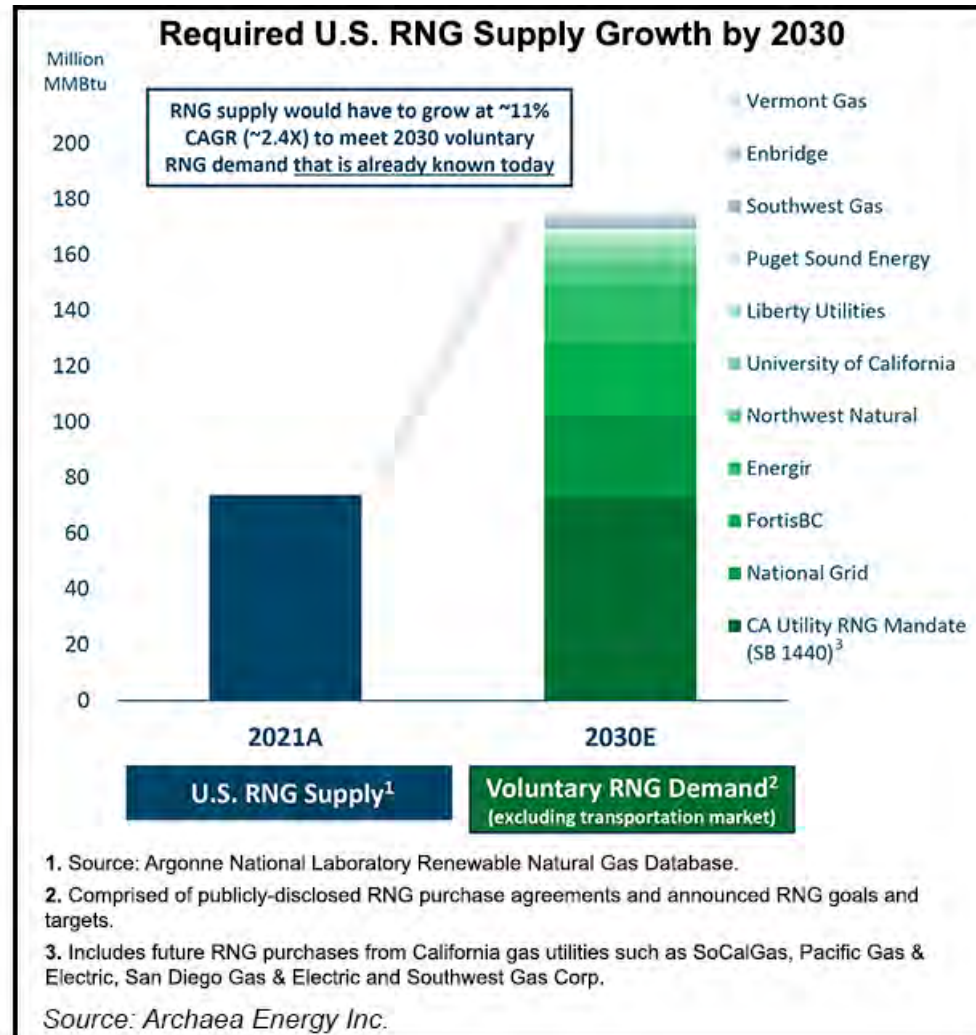


Anaerobic Digesters



RNG growth

Voluntary RNG demand
expected growth in 7 years





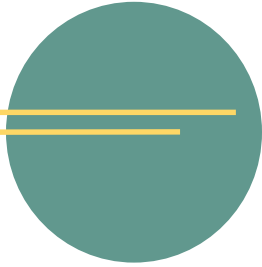
Carbon Offsets

- **Carbon offsets** are permits that allow a company to emit a certain amount of carbon dioxide and/or other greenhouse gasses into the air. One offset permits the emission of a mass equal to one ton of carbon dioxide to be neutralized. Carbon credits were devised as a market-oriented mechanism to reduce greenhouse gas emissions.
- How they are generated: Offsets can be generated through various ways such as land management through proper grazing and soil management, as well as planting trees, and direct air capture. To generate offsets a series of requirements must be met to verify the amount of CO₂ pulled from the atmosphere, including internal monitoring and external verification.





Questions?



- ▶ Karen Simpson
 - ▶ ksimpson@uetllc.com
 - ▶ 785-623-0125

- ▶ Hunter Kopseng
 - ▶ hkopseng@uetllc.com
 - ▶ 303-634-7419

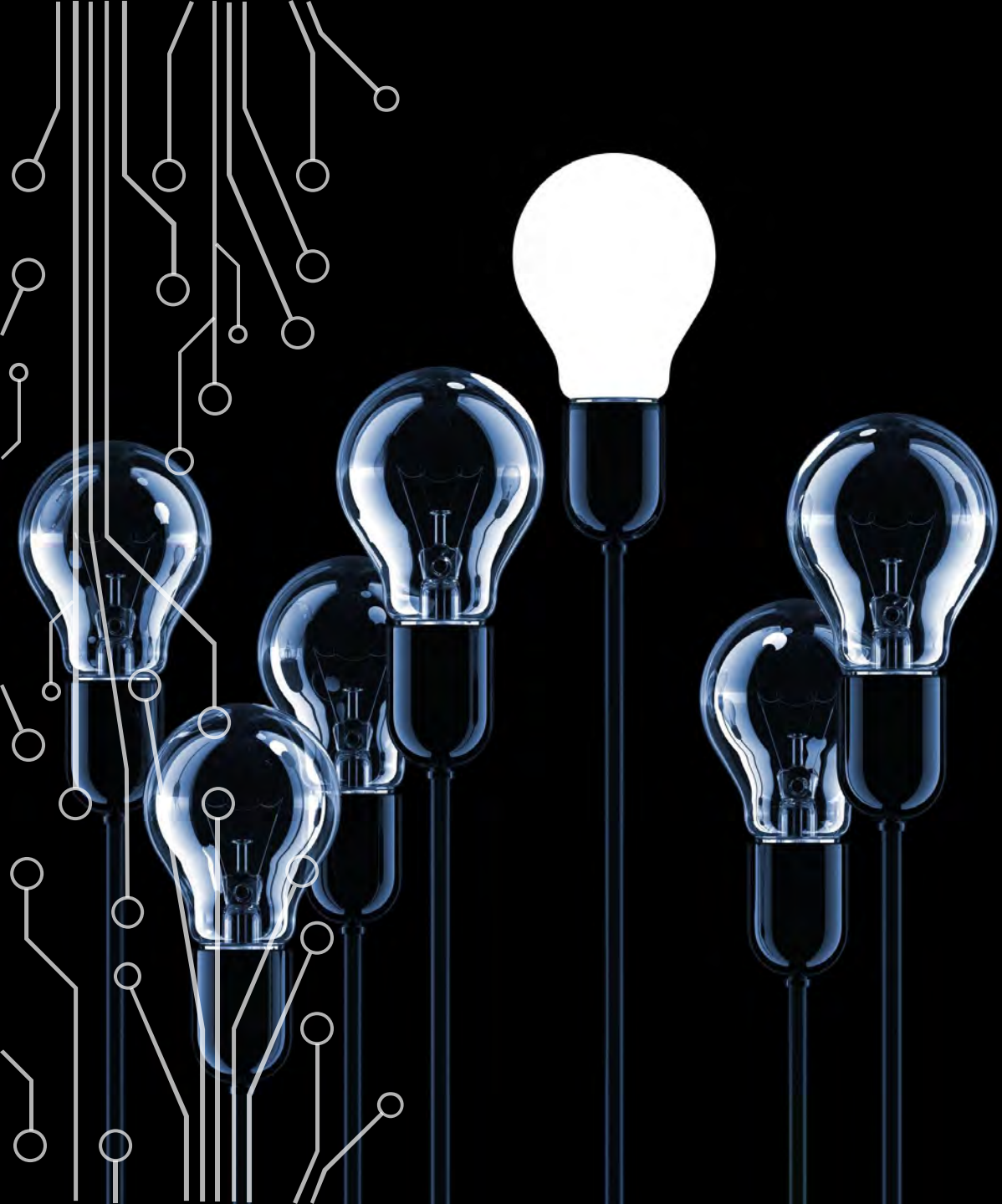
- ▶ Corson Purnell
 - ▶ cpurnell@uetllc.com
 - ▶ 214-725-7337

- ▶ Bryan Rizuto
 - ▶ brizuto@uetllc.com
 - ▶ 720-245-5771

- ▶ Thank You!

THE STATE OF LED IN SCHOOLS

Jared Blackney,
McBride Lighting



LED LIGHTING AND EVERYTHING THAT COMES WITH IT

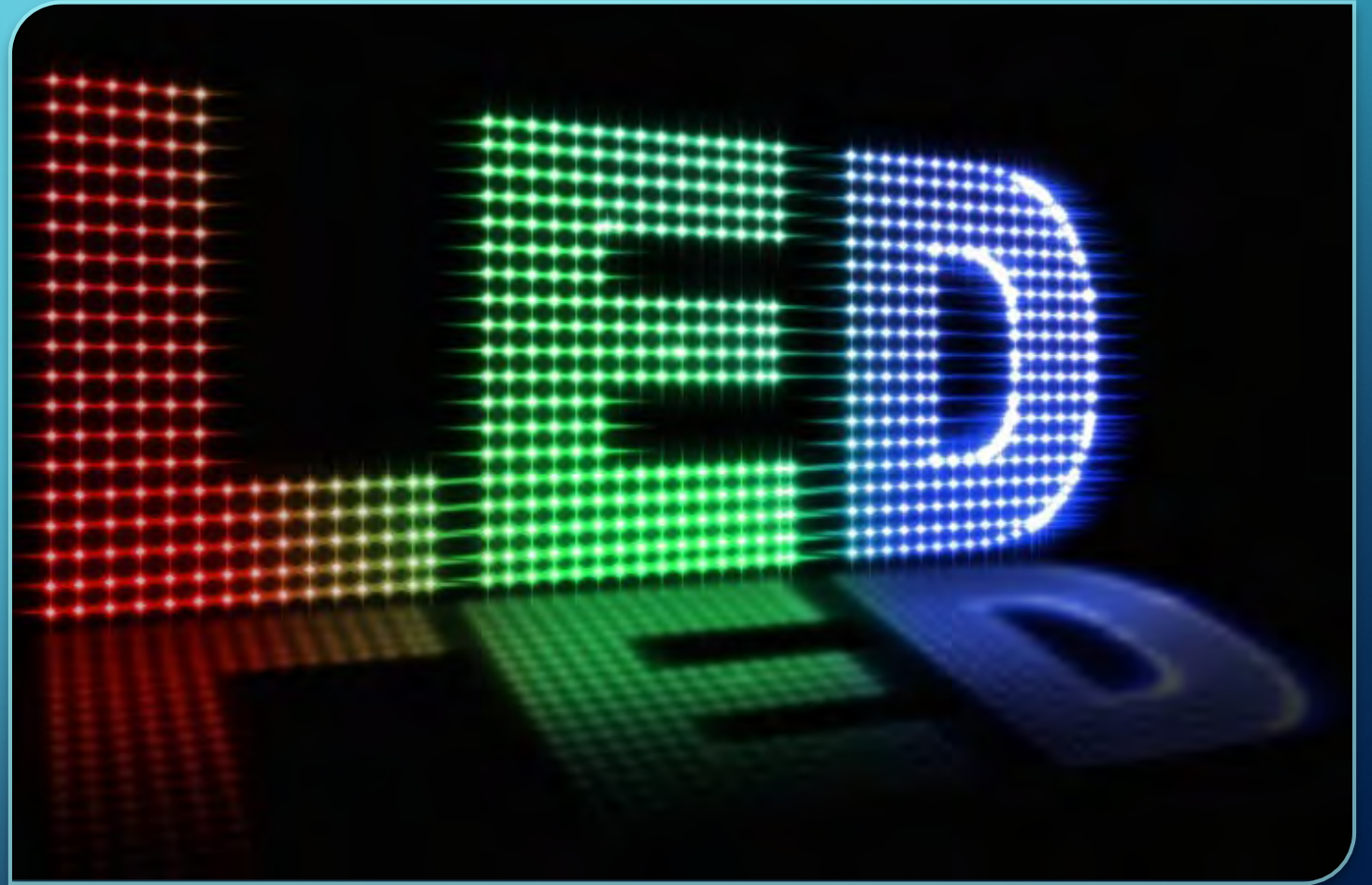
PRESENTER: JARED BLACKNEY CLMC,
CSLC, CLEP

VICE PRESIDENT

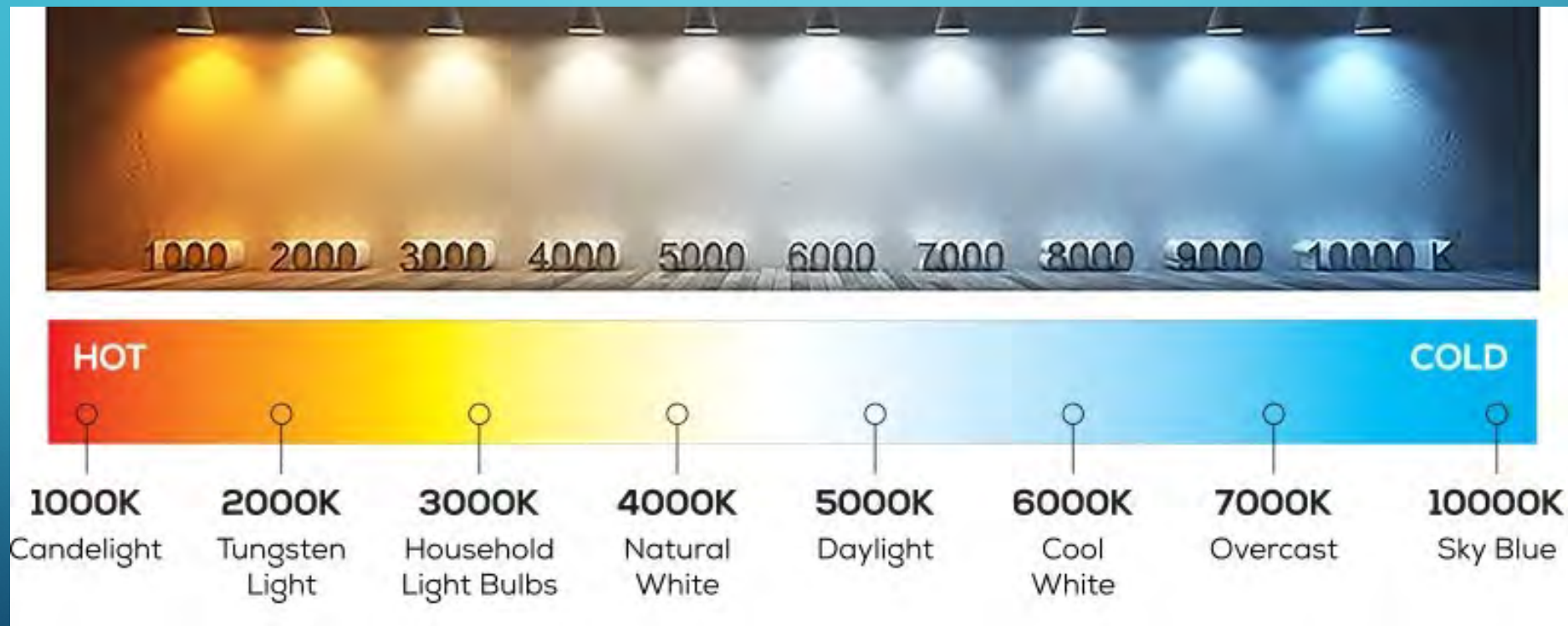
MCBRIDE LIGHTING INC

WHY CHOOSE LED LIGHTING

- Color Consistency
- Flexible CRI
- Color Tunable/Wattage Tunable
- Light Levels & Lumen Output
- Energy Efficiency
- Efficacy



WHAT COLOR DO YOU “HAVE” VS. WHAT COLOR DO YOU “NEED”?



WHAT IS CRI?

CRI 70



CRI 80



CRI 90



COLOR RENDERING INDEX

- When is CRI relevant
- What is the baseline
- Interior vs. Exterior
- CRI cost factors



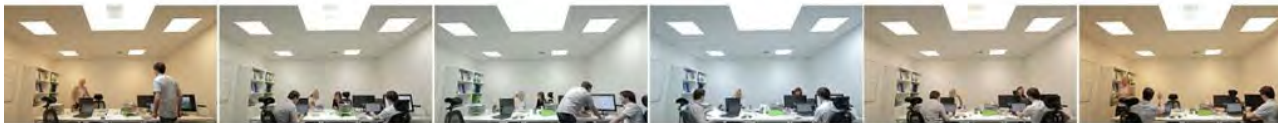
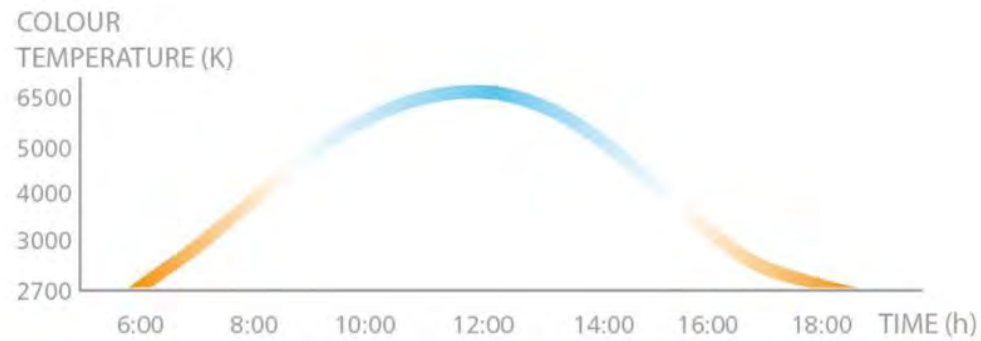
CIRCADIAN RHYTHM

- What is Circadian Rhythm
 - The term “**circadian rhythm**” refers to functions within the body that occur approximately every 24-hours. The word ‘circadian’ comes from Latin with ‘circa’ meaning ‘around’ and ‘diēm’ meaning ‘day’. While circadian lighting is a relatively new term, **circadian rhythms** have been observed for centuries in both plants and animals.
- Internal clock and your day to day



CIRCADIAN LIGHTING

- Expectations vs. Reality
- Existing Products that “work”
- Most are manual
- It is getting there



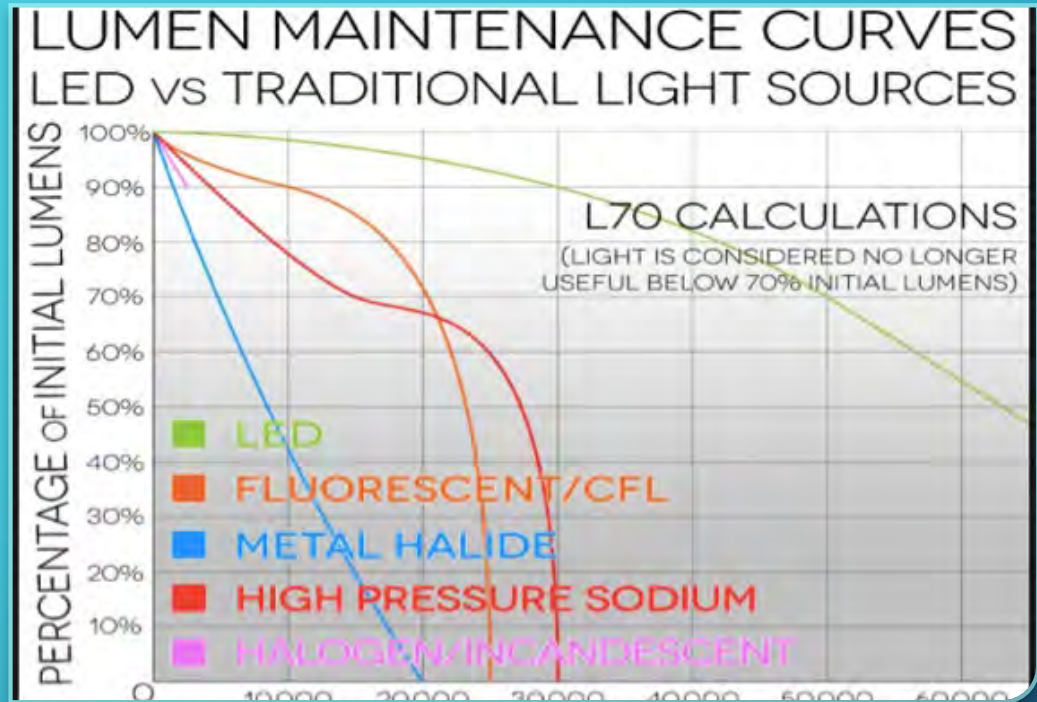
LIGHTING STANDARDS & IES STANDARDS

Application - Educational Facility ⁵	Horizontal Average (FC) ^{3, 6}	Maintained Horizontal Range (FC) ^{1, 2, 6}	Vertical Average (FC) ^{3, 6}	Maintained Vertical Range (FC) ^{1, 2, 6}
Classroom (General)	40	30 - 50	-	-
Gymnasium-Class I (Pro or Div. 1 College)	100	-	30	-
Gymnasium-Class II (Div. 2 or 3 College)	75	-	20	-
Gymnasium-Class III (High School)	50	-	150	-
Gymnasium-Class IV (Elementary)	30	-	100	-

Application - Office/Workplace ⁵	Horizontal Average (FC) ^{3, 6}	Maintained Horizontal Range (FC) ^{1, 6}	Vertical Average (FC) ^{3, 6}	Maintained Vertical Range (FC) ^{1, 6}
Open Office (Desk)	40	30 - 50	-	-
Private Office (Desk)	40	30 - 50	-	-
Conference Room (Table)	30	15 - 60	-	-
White board (Reading)	-	-	15	7.5 - 30
White board (Presenting)	-	-	30	15 - 60
Presentation Screen (Projector)	-	-	1.5	1.5 - 6
Lunch & Break Room	15	5 - 20	-	-
Stairs	5	2.5 - 10	3	1.5 - 6
Corridor	5	2.5 - 10	3	1.5 - 6
Filing (Intermittent)	15	7.5 - 30	10	5 - 20
Restroom (General)	5	2.5 - 10	3	1.5 - 6
Restroom (Wash Area)	15	7.5 - 30	20	10 - 40

- What is a Footcandle
- How do you measure it
- Why is it important

GENERAL PURPOSE BULBS LUMEN COMPARISON				
Lumens	Incandescent	HID	CFL	LED
250 lm	25W	18W	6W	2W-3W
560 lm	40W	29W	10W	3W-6W
800 lm	60W	43W	13W	7W-10W
1100 lm	75W	53W	18W	10W-15W
1600 lm	100W	72W	23W	15W-20W
2600 lm	150W	100W	42W	20W-30W



LUMEN OUTPUT

- WHAT IS A LUMEN
 - A MEASUREMENT OF VISIBLE LIGHT
- LUMEN MAINTENANCE

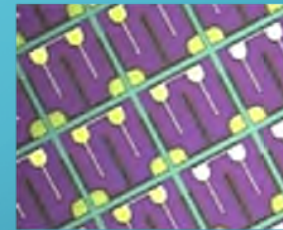
LED QUALITY

- LED chips are NOT all created equally
- How are they made?
- Fixture Testing
- Fixture and Lens Quality
- DLC and Energy Star
- Being Consistent



Substrate Production

- Raw materials
- Growing ingots
- Slicing
- Polishing



LED Die Fabrication

- Layering
- Masking / lithography
- Etching
- Die singulation



Packaged LED Assembly

- Die testing
- Die attach
- Encapsulation and optics
- Test and binning

BASIC TYPES OF LED PRODUCTS

- Type A vs. B vs. C
- Fixtures and Kits
- Controls
- Questions



OUTDATED LIGHTING AND HOW TO IDENTIFY IT

- Old Technology Types
 - Incandescent
 - CFL
 - Fluorescent
 - HID
 - Induction
- How to identify old lighting



HOW TO BUY LED LIGHTING

- The lighting pyramid scheme
 - Manufacturer (off shore)
 - Manufacturer (on shore)
 - Rep House
 - Distribution
 - Contractor
 - End User



WHERE TO BUY LED LIGHTING

- Buying Direct from the manufacturer
- Buying from the Rep
- Buying from Distribution
- Buying from the Contractor
- Internet buying is OK
 - Focus on the manufacturer not the price
 - Amazon
- Questions



PICKING THE RIGHT TEAM

- Lighting Contractor vs. Electrical Contractor
 - But why an LC and what qualifications should they have
 - Audit Capabilities
 - Install Experience
 - Subcontractors that subcontract
 - Low bid isn't always the best bid
 - Too many hands in the cookie jar
 - The schedule isn't real



CONTACT INFO

- Jared Blackney
- Vice President
- McBride Lighting Inc.
- Office 303-778-8787
- Cell 303-503-2502
- Jared@mcbritelighting.com



QUESTIONS



WE NEED DISTRICT HOSTS!

- January 26, 2023
 - **CSU Spur or APS**
- March 23, 2023
 - **Colo Spgs D11**
- May 11 or 12, 2023?
 - Mesa SD, Grand Junction



CASDEM STRATEGY — WHY?

What is your personal and/or professional why for doing the work you do in sustainability and energy management?

Jam Board

What is your personal and/or professional "why" for doing the work you do in sustainability and energy management?

I like to see the students gain an understanding that they can do something to help the environment

To improve the health of our most impacted communities

so my grandson has a world to grow up in

Making changes by educating the younger generation

for the children

Because kids need us to be their voice at the table for their future

Bettering the world for the future

Why not??

To use the gift we've been given, responsibly

Personal passion to make a positive impact for the future

To leave this planet a better place than when I found it.

All living things are impacted by climate change, but only humans are responsible for it

To live in a cleaner world.

A rewarding job technically is not a job

Because no else would do this job...?

I love the science of energy

Our district can "Do Better" than we are doing

to be able to go snowboarding in another 20 years

Empowering the younger generation

**Resource
Management**

```
graph TD; RM[Resource Management] --- EEJ[Engagement & Environmental Justice]; EEJ --- CIC[Curriculum, Instruction & Career]; CIC --- HW[Health & Wellness]; HW --- T[Transportation]; T --- BE[Built Environment]; BE --- RM;
```

**Engagement &
Environmental
Justice**

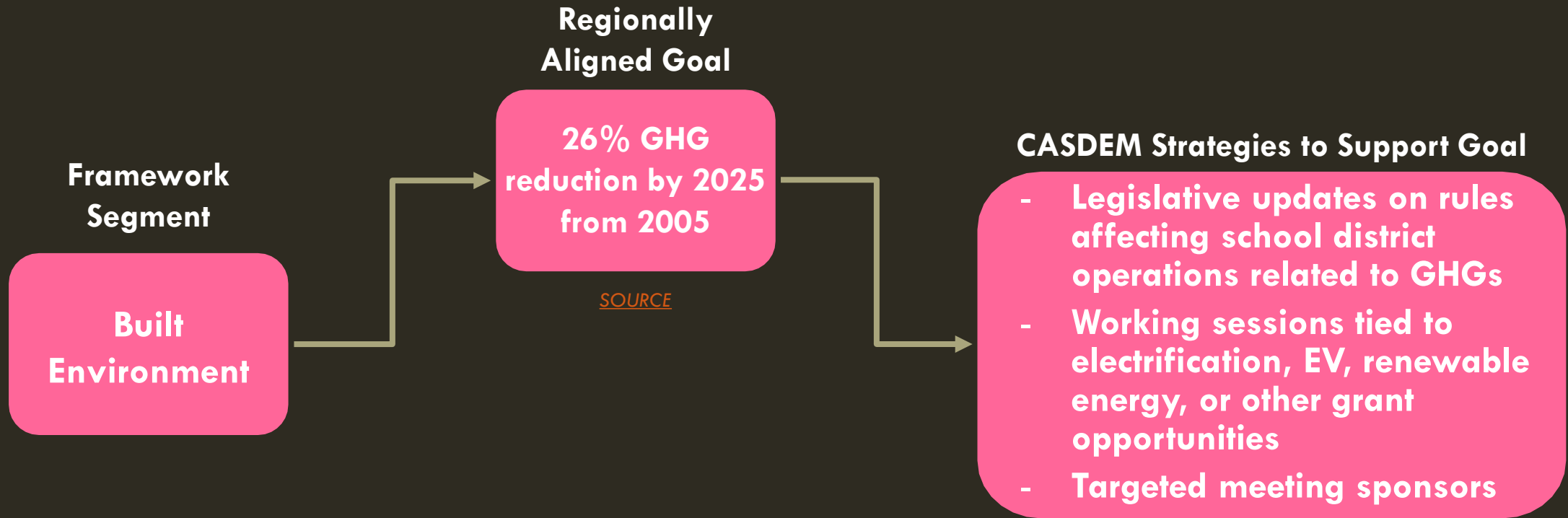
**Curriculum,
Instruction &
Career**

**Heath &
Wellness**

Transportation

**Built
Environment**

CASDEM STRATEGY DRAFT FRAMEWORK



EXAMPLE FRAMEWORK GOALS

CASDEM Strategy

RESOURCE MANAGEMENT

Focus Area Discussion

NICE SEEING EVERYONE!

Next meeting
January 26, 2023

DPS Cold Weather Sequence

DAREL LEEDY <dleedy@dpsk12.net>

Thu, Nov 17, 2022 at 11:53 AM

To: shannon.t.oliver@adams12.org, LEEANN KITTLE <leeann_kittle@dpsk12.net>

Hi Shannon,

Here is the DPS Cold Weather Sequence in our design standards. Please share with Beth as I do not have her email address. Thanks!

11. COLD WEATHER SEQUENCE

- A. A cold weather emergency sequence shall be built into to the BAS that enables DPS to manually control:
 - 1. Mixed Air temperature of RTU and AHU to 45 F.
 - 2. Set OA damper position to minimum or zero.
 - 3. Set the global building night set back temperature to the occupied temperature.
- B. The cold weather sequence shall automatically provide the following when outside air temperature is below 10 F (adj):
 - 1. Set the unoccupied temperature equal to the occupied temperature.
 - 2. close Outside air dampers when the average building temperature is more than 5 deg F below setpoint.
- C. Controls contractor shall coordinate with DPS Controls Engineer on implementation of this sequence.

Darel Leedy

Supervisor, Building Optimization | Sustainability

Main: 720.423.4214 | Cell: 720.940.4005

2800 W. 7th Ave.| Denver, CO 80202 |<http://www.dpsk12.org>

LIGHTING IN THE STUDENT ENVIRONMENT

“LIGHT IS THE MOST IMPORTANT ENVIRONMENTAL INPUT, AFTER FOOD AND WATER, IN CONTROLLING BODILY FUNCTIONS.”

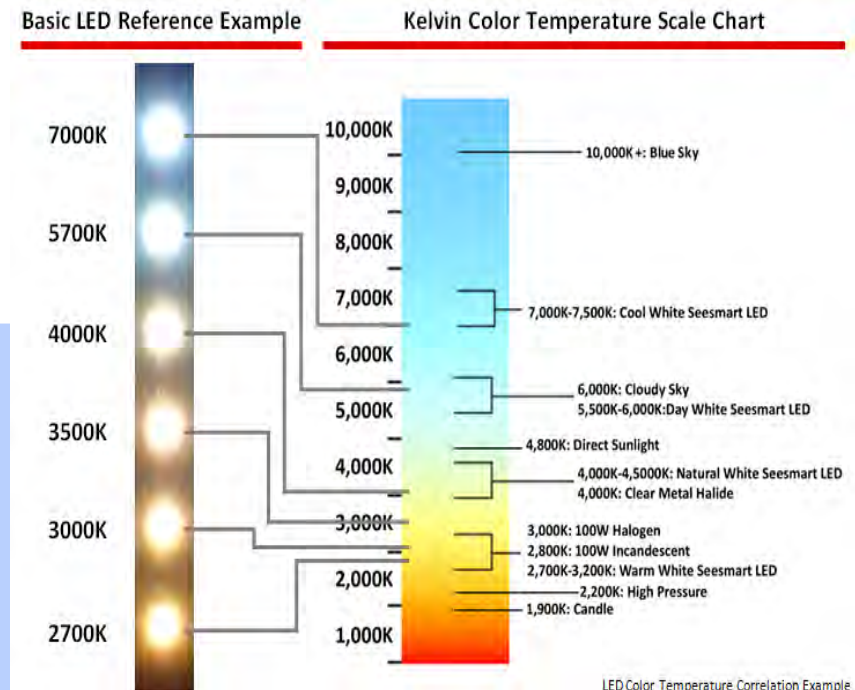
-WURTMAN (1975) THE EFFECTS OF LIGHT ON THE HUMAN BODY, SCIENTIFIC AMERICAN

LIGHTING IN THE STUDENT ENVIRONMENT

- Where are we individually with lighting
- Lighting Background
- Lighting in Schools
- Adjustable CCT
- Review of Five Studies
- Takeaways

CONCEPTS

- Perception for blue light
- Visible light to humans ranges from 380nm – 780 nm
 - actual colors, to get cool white or warm white, you're mixing different colors - CCT
- Daylighting and circadian rhythm
- Cones and Rods
- RGCs 3rd photoreceptor linked to “superchiasmatic nucleus”
 - 1998, controlling cortisol and melatonin
- CRI
 - “Full Spectrum”
- Kelvin Scale (Lighting Color)
- Evolution of Lighting



PRODUCTS

- **Phillips - SchoolVision/Tunable White**
- <http://www.usa.lighting.philips.com/products/product-highlights/tunable-white-technology.html>
- **Sylvania – Tunable White**
- **Cree – SmartCast**
 - 3000K-5000K
 - <http://www2.cree.com/smartcast-landing-page>
- **PlanLED– Beetle**
 - 2700K - 6500K
 - <http://www.planled.com/archives/portfolio-item/beetle>



LIGHTING IN OUR SCHOOLS

Survey

- **How many LED schools do we have?**
- **Plans to convert or redesign?**

Jeffco

- **Lighting Audit – Bell MS**
- **% of energy use**
- **Annual cost**
 - Consumption and baseload shift: \$1.1M + \$X00K - ~\$0.10/SF/yr
- **Opportunities with updates**
 - Expected savings from retrofit
 - Dimming, maintenance, rebates, improved integration, less color degradation, lowering LPD for 0-25

LIGHTING IN TODAY'S SCHOOLS

- Practice of overdesigning
 - Measurements
 - Additional Savings
 - Average lx
- Before and after comparison

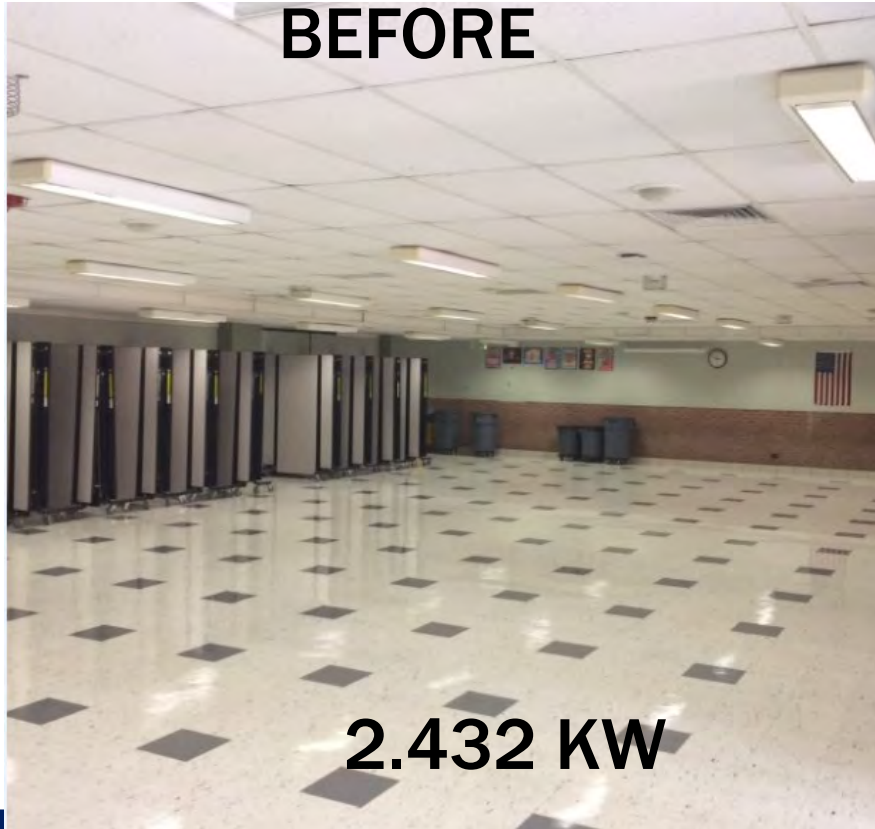
Applications and Tasks ^a	Notes	Horizontal (E_h) Targets			
		Visual Ages of Observers (years) where at least half are			
		<25	25-65	>65	
		Category		Gauge	
CLASSROOMS	(Graphic Arts continued)				
Permanent/Temporary	Awards, student art, plaques				
Dimensional	E_h and E_v @artworks				
Dark finish	<50% reflectance		Avg = 5 times E_h of surrounding space		
Light finish	≥50% reflectance		Avg = 3 times E_h of surrounding space		
Flat					
Horizontal	E_h and E_v @artworks				
Dark finish	<50% reflectance		Avg = 5 times E_h of surrounding space		
Light finish	≥50% reflectance		Avg = 3 times E_h of surrounding space		
Vertical	E_h and E_v @artworks				
Dark finish	<50% reflectance				
Light finish	≥50% reflectance				
- Drafting and Design	On drafting board or table				
- Blueline blueprint	Also see READING AND WRITING/Xerograph	R	250	500	1000 Avg
- CAD (exclusively)	See READING AND WRITING/VDT Screen and Keyboard				

• General Classrooms					
• Learning/teaching	Interactive experience				
• AV (dedicated AV viewing)	E_h @2' 6"; E_v @4' AFF	K	25	50	100
• Chalkboard					
• Dedicated VDT screens	CSA/ISO Type I and II negative polarity screens. ¹ E_h @2' 6"; E_v @4' AFF	N	75	150	300
• Hardcopy and writing	Variety of paper tasks. ¹ E_h @2' 6"; E_v @4' AFF	Q	200	400	800
• Tack board					
• White board					

20 FC gauges on desk

CAMPBELL ES CAFETERIA

BEFORE



2.432 KW

5472KWH/YR

AFTER



.72 KW

1620 KWH/YR

INSTALLED COST: \$864

ANNUAL SAVINGS: \$385.20

PERCEPTION OF LIGHT

- **Flicker**
 - Impact
- **Color**
- **Awareness of CCT**
- **Influence of room conditions**
- **“Cool white fluorescent lighting can drastically improve the behavior of students who are hyperactive or have learning disadvantages” – Ott (1976)**
- **Behavior**

SOME FINDINGS

Cheatum and Hammond (2000) Visual impairments can induce behavioral problems in students which can impact concentration and motivation. 20% of students are estimated to encounter visual problems.

(When comparing fluorescent to full-spectrum fluorescent)

Winterbottom and Wilkins (2009) Found that the imperceptible 100Hz flicker from fluorescent lights were present in 72/90 (80%) of the UK classrooms in the study.

Ott (1976) revealed that cool white fluorescent light can improve behavior of hyperactive students or those with learning disadvantages. Concluded that “hyperactivity is partly due to a radiation stress condition”.

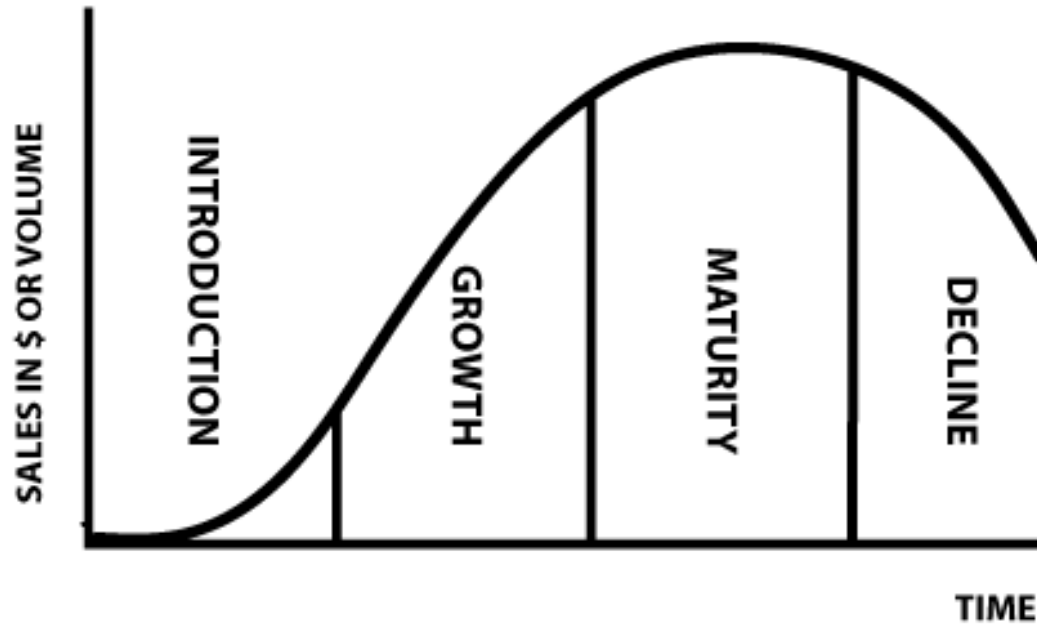
TUNABLE WHITE DEMO

- <https://www.youtube.com/watch?v=MS91xT4QpGk>
- Sylvania Lighting Demo
 - 3000K, 3500K, 4200K, 5000K

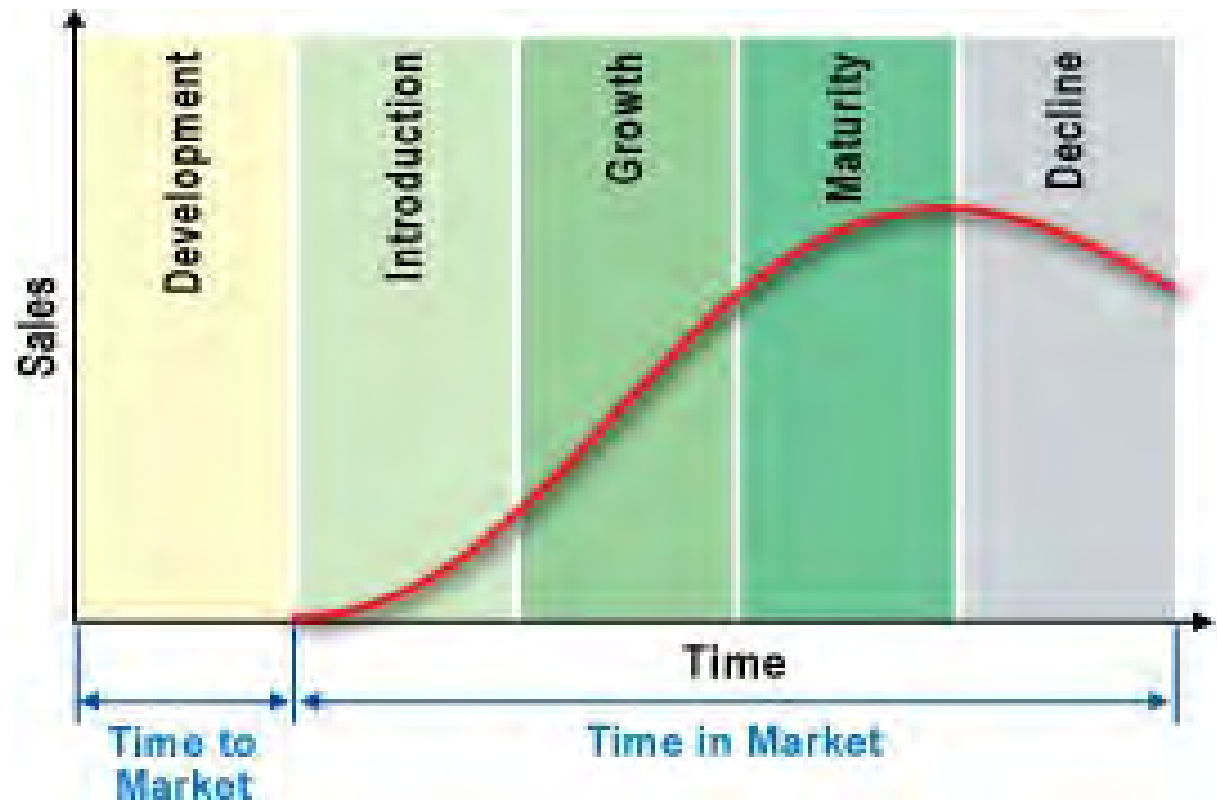
- Common Settings:

	Color	lx
Calm	2900K	300
Standard	3500K	300
Focus	6500K	1000
Energy	12000K	650

PRODUCT CYCLE



PRODUCT CYCLE



STUDY SECTION – A FEW PROBLEMS

- **The technology has different names**
 - Philips – 4 names for technology in these papers alone
- **Each study will use the same terms to describe only the extremes tested**
 - “Cool” “Warm” “Dim” “Bright”
- **Manufacturers have skipped the R&D and education phase of the product cycle.**
- **No two studies test the same lighting settings...**
 - Every illuminance level tested is higher settings than TLH levels...
- **There's not much out there.**
- **Few conclusions have been made.**
- **Most studies lack significant findings. Some findings are disputed.**
- **Tremendous overlap of relevant technical disciplines.**

EFFECTS OF INDOOR LIGHTING ON MOOD AND COGNITION

IGOR KNEZ Royal Institute of Technology, Sweden

1995, Journal of Environmental Psychology

- Testing of two successive hypotheses
- Two experiments conducted:
 - 96 subjects aged 18-55
 - Daylight removed
- Tested for memory, problem-solving, free recall, performance appraisal, mood measure, room light evaluation – sorted by gender
- Study was in 1995, these lights were neither dimmable nor LEDs.

	Color	lx	lx
A	3000K	300	
B	4000K		1500
Exp 1	95 CRI		
Exp 2	55CRI		

FINDINGS

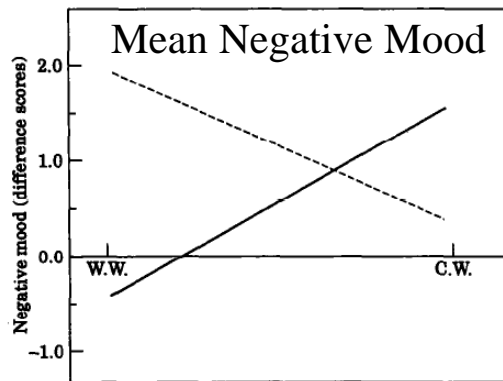


FIGURE 3. Mean negative mood in respective gender, as a function of 'warm' (w.w.) and 'cool' (c.w.) white light source (— = ♀; - - - = ♂.)

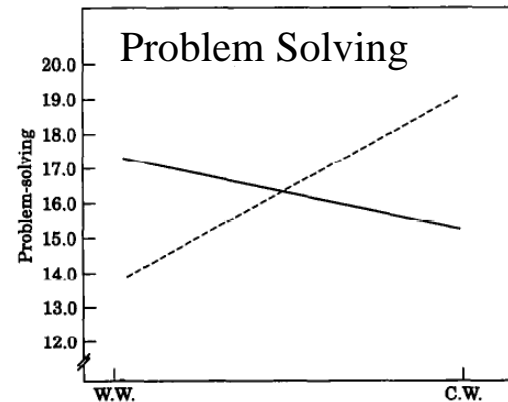


FIGURE 4. Mean problem-solving performance in respective gender, as a function of 'warm' (w.w.) and 'cool' (c.w.) light source. (— = ♀; - - - = ♂.)

- Males Dotted line
- Females Solid line
- CCT Compromise?

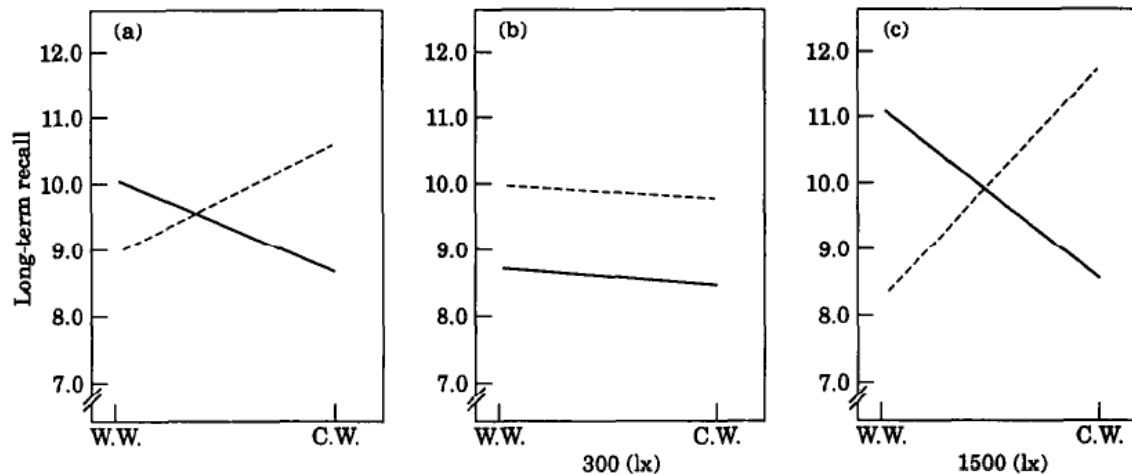


FIGURE 5. Mean long-term recall performance in respective gender, as a function of 'warm' (w.w.) and 'cool' (c.w.) white light source (a), in low (b) and high (c) illuminance conditions. (— = ♀; - - - = ♂.)

- No impact when dim
- Sig improvement for females

FINDINGS

- Males performed better under warm dim condition

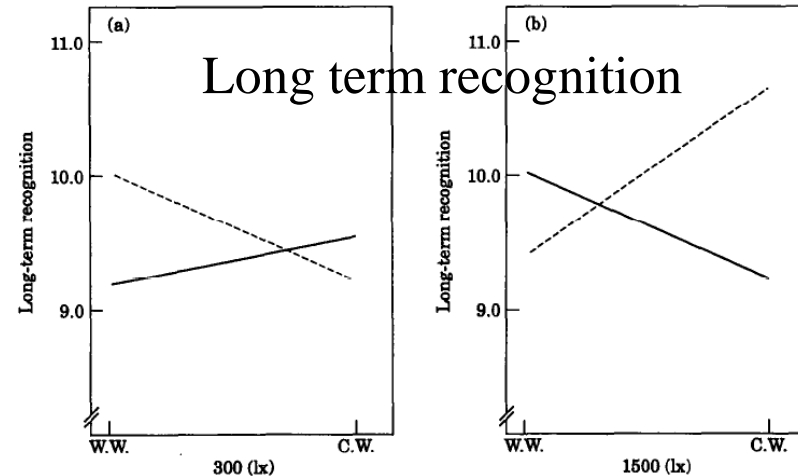


FIGURE 6. Mean long-term recognition performance in respective gender, as a function of 'warm' (w.w.) and 'cool' (c.w.) white light source, in low (a) and high (b) illuminance conditions. (— = ♀; - - - = ♂.)

- Discernable differences were Not Significant on warm test results. In either exp 1 or 2
- Females problem solving and long term memory were significantly enhanced in “warm” light
 - “Cool” light created this effect for Males
- Hypothesis confirmed - Mood impacts performance and has a correlation to color temperature.

ILLUMINATING THE EFFECTS OF DYNAMIC LIGHTING ON STUDENT LEARNING

Michael S. Mott The University of Mississippi

Daniel H. Robinson The University of Texas Austin

- Overview of lighting on humans and learning - **handouts**
- Testing impact of Focus lighting on ORF
- Experiment:

Schoolvision

	Color	lx	lx
Normal	3500K	500	
Focus	6500K		1000

- Eighty-four 7-8 year olds, Mid-South US
 - Modified lighting in one group, normal in the other
 - Focused used during “fluency” exercises
 - Testing under Normal conditions only*
 - Blinds drawn during study
- Calm and Normal settings available to modified group

ILLUMINATING THE EFFECTS OF DYNAMIC LIGHTING ON STUDENT LEARNING

- SchoolVision (Tunable White) 2900K-12000K, < 1000lx
 - Calm – 2900K, 300lx
 - Standard – 3000K–4000K, 300lx
 - Focus – 6500K, 1000lx
 - Energy – 12000K, 650lx
- Results:
 - Lighting Group ORF scores increased by 34 points, Control by 18 points
 - Found no impact of motivation or concentration
 - Unlike Knez (under very different conditions)

A COMPARISON OF TRADITIONAL AND HIGH COLOUR TEMPERATURE LIGHTING ON THE NEAR ACUITY OF ELEMENTARY SCHOOL CHILDREN

SM Berman Lawrence Berkeley National Lab
Lighting Research and Technology 38,1 2006

- **Testing of 27, 10-11 year olds under different CCT by an optometrist**
 - 6500K and 4100K listed, 3620K 5500K measured at H-Surface
 - 350lx
- **Takeaways:**
 - Higher CCT Light narrows the pupil
 - Provides greater perception of brightness
 - Light Rays → central region of the eye
 - Best Optical Quality
- **Conclusion – could save energy by...**



PAPER 3 – LBNL 2006

APPLICABILITY AND EFFICACY OF VARIABLE LIGHT IN SCHOOLS

Claus Barkmann Center for Psychosocial Medicine, Hamburg
Physiology and Behavior 2012

*****Authors were financially supported by Philips Lighting Hamburg*****

- To determine if “VL” in classrooms improves:
 - (1) Student concentration
 - (2) Student reading speed
 - (3) Student achievement and the classroom atmosphere
- Experiment: Two schools with two classrooms each (IG and CG)
 - Standardized 45 min test
 - 1st Test Standard Setting both groups
 - 2nd Test Standard in CG, Concentrate in IG

	Color	lx
Standard	4000K	300
Concentrate	5800K	1060
Activate	11000K	675
Relax	3500K	325
Ext. Relax	3500K	275

APPLICABILITY AND EFFICACY OF VARIABLE LIGHT IN SCHOOLS

Findings

- **16.8% improvement in reading comprehension in IG compared to 7.1% in CG**

Feedback

- *Concentrate*, *Activate* and *Relax* were used most often
- Students gave *Concentrate* a 3.4 on a 5 point rating scale
- 70.5% of students recommended using VL

	Color	lx
Standard	4000K	300
Concentrate	5800K	1060
Activate	11000K	675
Relax	3500K	325
Ext. Relax	3500K	275

LIGHTING AFFECTS STUDENTS' CONCENTRATION POSITIVELY: FINDINGS FROM THREE DUTCH STUDIES

PJC Slegers University of Twente, Enschede

Lighting Research and Technology 2012

*** Third Authors were employed by Philips Lighting Eindhoven***

- 4 Settings available “Dynamic Lighting”
- Daylighting included, but not discussed
- Exp 1: 96 Students in Grade 4 and 6
 - Testing concentration
 - Pretest normal lighting 300 lx 4000K
 - Test 1 and 2 - “Focus”
 - Pretest – 10/23, Test 1 - 11/24, Test 2 - 12/2
- No conclusions:
 - Potential learning identified, and errors made

	Color	lx
Calm	2900K	300
Standard	3500K	300
Focus	6500K	1000
Energy	12000K	650

- **Energy setting.** This setting is intended to be used to activate the pupils at the start of the day or after lunch. The average horizontal illuminance measured at desk level is 650 lx, and the CCT is 12 000 K (a ‘cold’, blue-rich white light.)
- **Focus setting.** This setting aids concentration during challenging tasks, such as exams and tests. The average horizontal illuminance measured at desk level is 1000 lx with a CCT of 6500 K (a bright white light).
- **Calm setting.** This setting brings a relaxing ambience to support independent and collaborative learning. The average horizontal illuminance measured at desk level is 300 lx with a CCT of 2900 K (white light with a warm, red colour tone).
- **Standard setting.** This lighting setting is used for regular classroom activities. The average horizontal illuminance measured at desk level is 300 lx, and the CCT is 3000–4000 K (standard white light as commonly used in indoor workplaces).

LIGHTING AFFECTS STUDENTS' CONCENTRATION POSITIVELY: FINDINGS FROM THREE DUTCH STUDIES

***** Third Authors were employed by Philips Lighting Eindhoven*****

- Study 2: 44 Students in Grade 4 and 6
 - **Changing Illuminance, not CCT
 - Testing concentration
 - Pretest – 1/20, Test 1 – 2/3, Test 2 – 2/17
 - Pretest normal lighting 350 lx 3000K
 - Test 1 and 2 – Constant “Focus” 1/21-2/18
 - While all students improved, Exp Group improved more

Study 2		
	Color	lx
Experiment	3000K	750
Control	3000K	380

Table 7 Average scores and standard deviations of concentration performance for three measurement times (Study 2)

Classroom	N	Pre-test	Post-test (1)	Post-test (2)
		Mean (SD)	Mean (SD)	Mean (SD)
Experimental	18	158.56 (21.99)	192.00 (26.31)	206.89 (29.97)
Control	19	158.79 (26.56)	166.26 (27.82)	178.32 (30.81)

ALSO...

- Heschong 2002 – statistical analysis of three school districts and amount of daylight. Found that increased daylight and skylight areas increased reading and math scores.

TAKEAWAYS

- **KNEZ**
 - Mood impacts performance and has a correlation to color temperature.
 - Females perform better at warmer color temps in the study men at cooler
- **MOTT**
 - ORF scores increased more in the IG vs CG
- **LBNL**
 - Cooler light can lead to energy savings – pupils and perception
- **BARKMANN**
 - Reading Comprehension increased by 16.8% in IG vs 7.1% in CG
 - Great feedback from students and teachers
- **SLEEGERS**
 - Under constant exposure of higher illuminance concentration improved
- **MORE RESEARCH IS NEEDED**

WHY IS IT ALL SO CONFUSED?

- Product cycle issues...
- Evolution of the industry, only recently are options available
- Many companies.
- Quickly changing industry.
- Large companies are facing new challenges.
- Tremendous overlap of relevant technical disciplines.
- Academics usually don't study design practices.

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1995

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