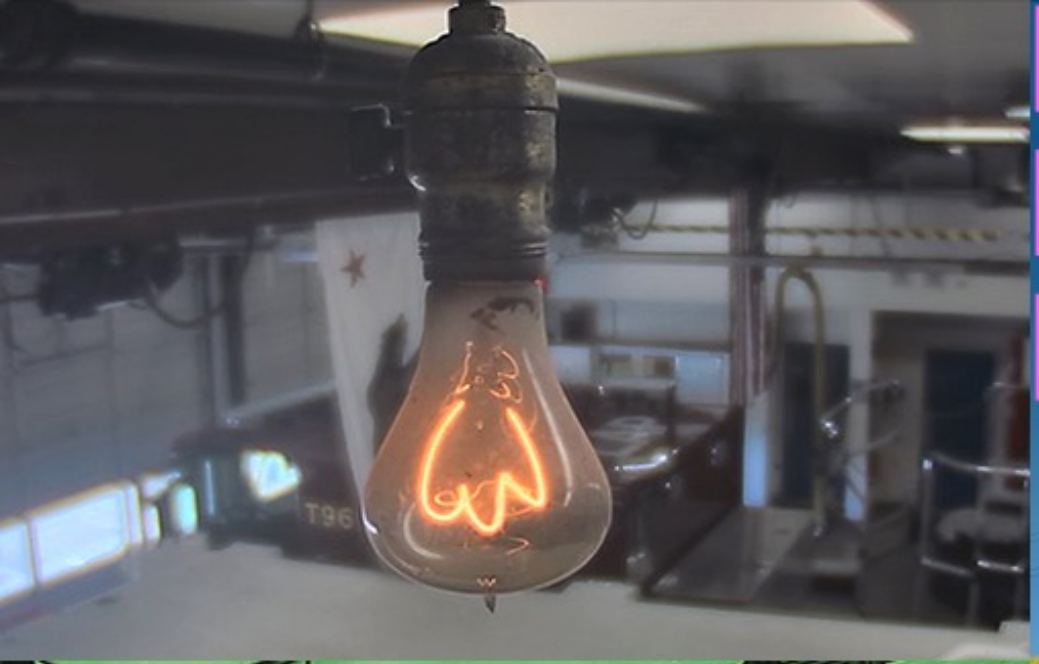
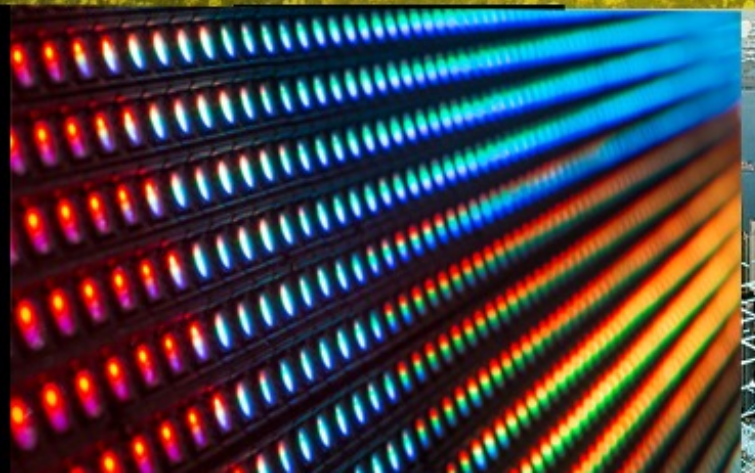


Lightbulbs, Luminaires, Lifetime

Scenarios for the Future of Lighting



Exponation

AIA Provider Number: 70119700

Lightbulbs, Luminaires, Lifetime – Scenarios for the Future of Lighting

Session S06

Clifton Stanley Lemon, IES

Date 9.25.19

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

In the lighting industry today rapid change, proliferation of technologies, and evolving global economic realities create considerable uncertainty and risk for manufacturers and designers. How do we know what to build and install and when? When will components or systems become obsolete? This talk looks at economic, historical, cultural, and technical facets of these questions, connects them to the drivers of change, and presents useful scenarios for the future of lighting.

Learning Objectives

1. Explore the history and economics behind our current electrical and lighting infrastructure
2. Analyze the complexity of strategic planning questions for product and design companies
3. Investigate new approaches to innovation in technology for the built environment
4. Identify new directions in the design and deployment of lighting and electrical systems that adapt to the future

Burning Questions

Bulbs, luminaires, modules, or something else?

Aren’t some LED “bulbs” actually luminaires?

What do we build and when do we build it?

Why are manufacturers so obsessed with lifetimes?

Why don’t we just build a new electrical infrastucture?

Why put new technology into old forms?

Why don’t we design for SSL’s full capabilities?

We’ve reached peak lighting efficiency- now what?

How can we make better forecasts?

Roadmap

1. Evolution of the Lightbulb
2. Evolution of Luminaires
3. Lifetimes of Lighting Systems
4. Building Lifetime & Cycles
5. Networks & the Grid
6. The Good Old Days
7. MAYA & Designing the Future
8. Prophesy, Prediction, & Scenarios
9. Four Shades of Future

1. Evolution of the Lightbulb

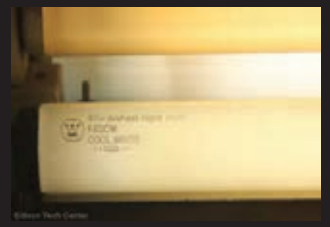
Light Bulb History's Greatest Hits

Filament Light Bulb

1890

Thomas Edison
Brilliant Inventor guy

Fluorescent Tube



1940

Unknown
Engineer Guys

CFL

1974

Unknown
Engineer Guy

Blue LED

1993-94

Shuji Nakamura
Brilliant Nobel
Laureate

L Prize
First LED
90 LPW
900 lm

2011

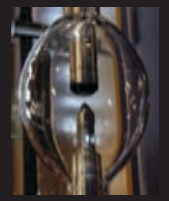
PHILIPS

> $3 90+ CRI
Dimmable
A Lamp
800 lm

2019

Generic

A Deeper Look Back



1806 First Arc Lamp

1850 First Constant Electric Light

1877-78 Early Edison Lamp

1882 Edison Whole Lighting System

1890 Edison Filament Lamp

1901 Mercury Vapor Lamp: Fluorescent Tube Percursor

1904 Tungsten Filament Lamp 10 LPW

1913 First Detailed Studies of Electroluminescence

1924 Incandescent Lamp Efficiency Doubles

1925 Early Fluorescent Prototypes

1926 Phoebus Cartel Founded

1939 First Fluorescent Tubes Displayed

1951 Fluorescents Overtake Incandescents

1962 First LED Holonyak

1973 First Oil Crisis

1974 CFL

1978 Display LEDs Hit Market

1993 Blue LED

2000 DOE Pushes LEDs

2011 L Prize First LED 90 LPW 900 lm

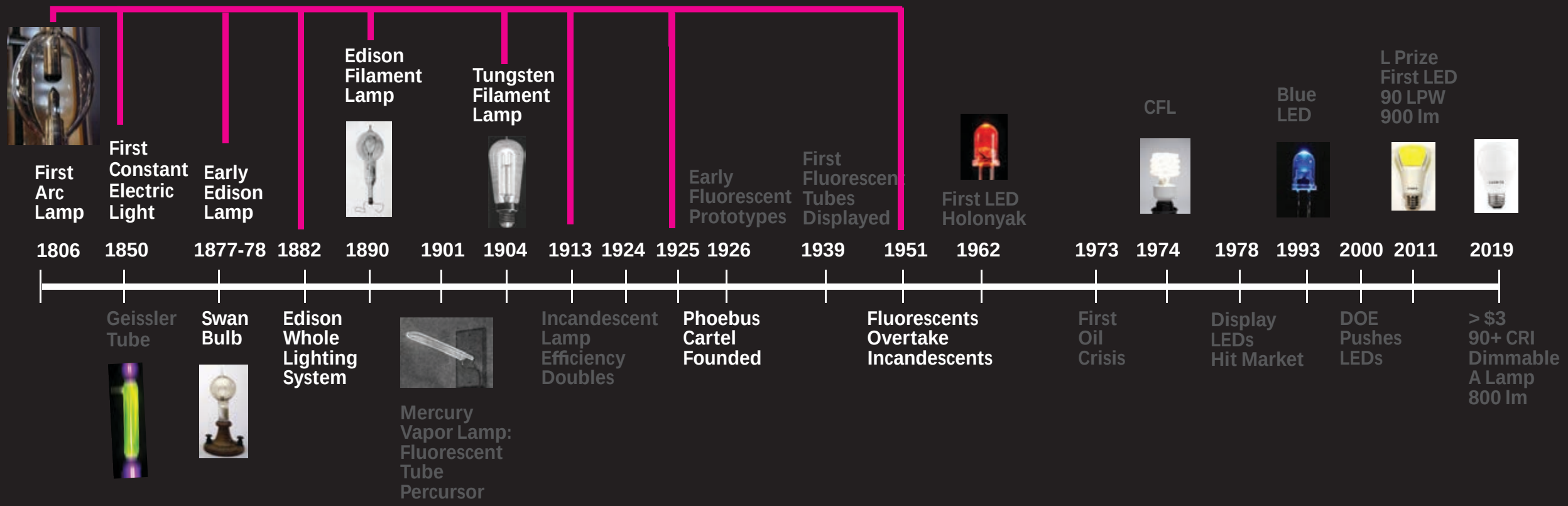
2019 > $3 90+ CRI Dimmable A Lamp 800 lm

1806 1850 1877-78 1882 1890 1901 1904 1913 1924 1925 1926 1939 1951 1962 1973 1974 1978 1993 2000 2011 2019

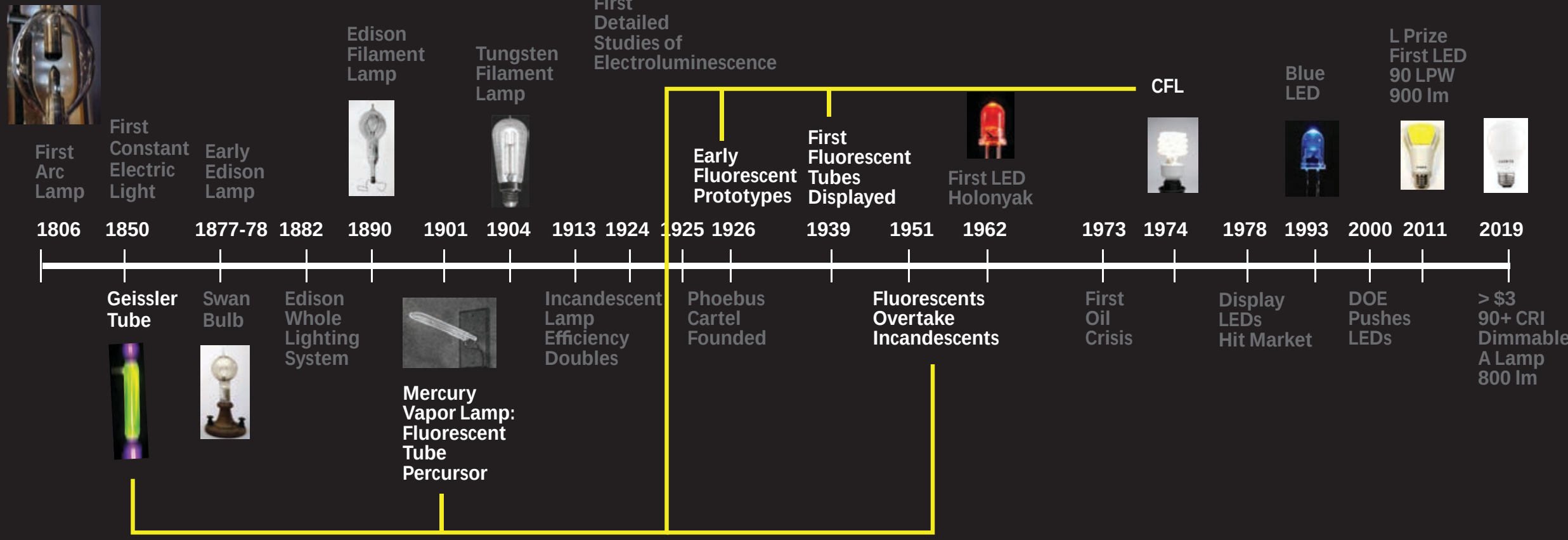
Geissler Tube

Swan Bulb

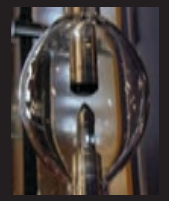
Connections- Incandescent



Connections- Fluorescent



Connections- LED



1806 First Arc Lamp

1850 First Constant Electric Light

1877-78 Early Edison Lamp

1882 Edison Whole Lighting System

1890 Edison Filament Lamp

1901 Mercury Vapor Lamp: Fluorescent Tube Percursor

1904 Tungsten Filament Lamp

1913 Incandescent Lamp Efficiency Doubles

1924 First Detailed Studies of Electroluminescence

1925 Phoebus Cartel Founded

1926 Early Fluorescent Prototypes

1939 First Fluorescent Tubes Displayed

1951 Fluorescents Overtake Incandescents

1962 First LED Holonyak

1973 First Oil Crisis

1974 CFL

1978 Display LEDs Hit Market

1993 Blue LED

2000 DOE Pushes LEDs

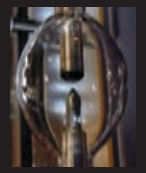
2011 L Prize First LED 90 LPW 900 lm

2019 > $3 90+ CRI Dimmable A Lamp 800 lm

Geissler Tube

Swan Bulb

Connections - Other Forces



1806 First Arc Lamp

1850 First Constant Electric Light

1877-78 Early Edison Lamp

1882 Edison Whole Lighting System

1890 Edison Filament Lamp

1901 Mercury Vapor Lamp: Fluorescent Tube Percursor

1904 Tungsten Filament Lamp

1913 First Detailed Studies of Electroluminescence

1924 Incandescent Lamp Efficiency Doubles

1925 Early Fluorescent Prototypes

1926 Phoebus Cartel Founded

1939 First Fluorescent Tubes Displayed

1951 Fluorescents Overtake Incandescents

1962 First LED Holonyak

1973 First Oil Crisis

DC/Solar/Battery Whole Systems

Climate Change & Environment

1974 CFL

1978 Display LEDs Hit Market

1993 Blue LED

2000 DOE Pushes LEDs

2011 L Prize First LED 90 LPW 900 lm

2019 > $3 90+ CRI Dimmable A Lamp 800 lm

DOE Pushes New Grid

LEDs Overtake Incandescents & Fluorescents (Installed)

Illumigeddon

Geissler Tube

Swan Bulb

Recurring Themes

Not enough light

Too much light

Control of Light

Nostalgia & Backlash

Fear of Change

Chromaticity

Health & Wellness

Equal Access to Light

Quality of Light

Power Transmission

Energy Efficiency

Reliability

Thermal Management

Glare

Lifetime

Maintenance

Reducing Wiring

Price Control

ROI

2. Evolution of Luminaires

Fixed

Mounted Torch
Fuel
+ Fire
(+Fixture)

Gas Lamp
Fuel
+ Energy Network
+ Fixture
+ FIre

Incandescent Lamp
DC/AC Grid
+ Electricity
+ Fixture
+ Bulb

SSL Lamp
AC Grid
+ Electricity
+ Fixture
+ "Bulb"

SSL Device
Device
+ Network(s)
+ Electricity
+ Data

Portable

Torch
Stick
+ Fire

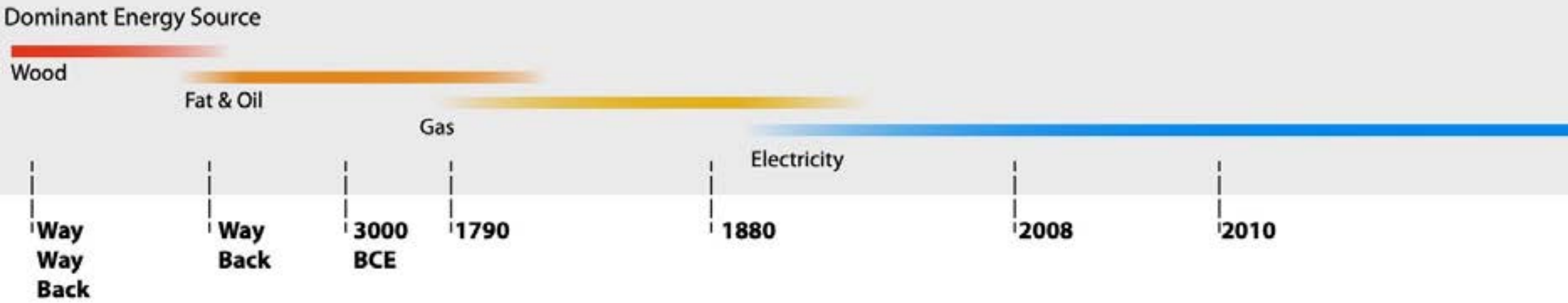
Oil Lamp
Vessel
+ Fuel
+ Fire

Candle
Fuel
+ Fire
(+Fixture)

Kerosene Lamp
Fuel
+ Fixture
+ Fire

Flashlight (Torch)
Fixture
+ Bulb
+ Battery

SSL Device
Device
+ Data Network
+ Battery
+ Data

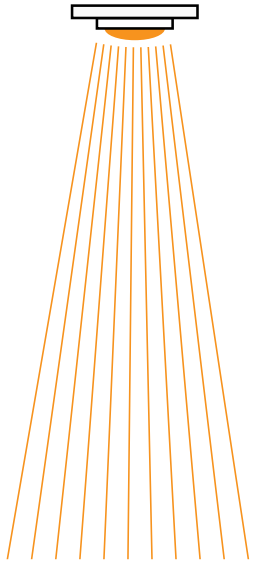


Omnidirectional vs Directional

Design Strategy:
Start with too much light, then shade, block, or redirect it, mostly inefficiently, mostly with metal, not optics.

Incandescent
5% of power converts to visible light, 95% to heat

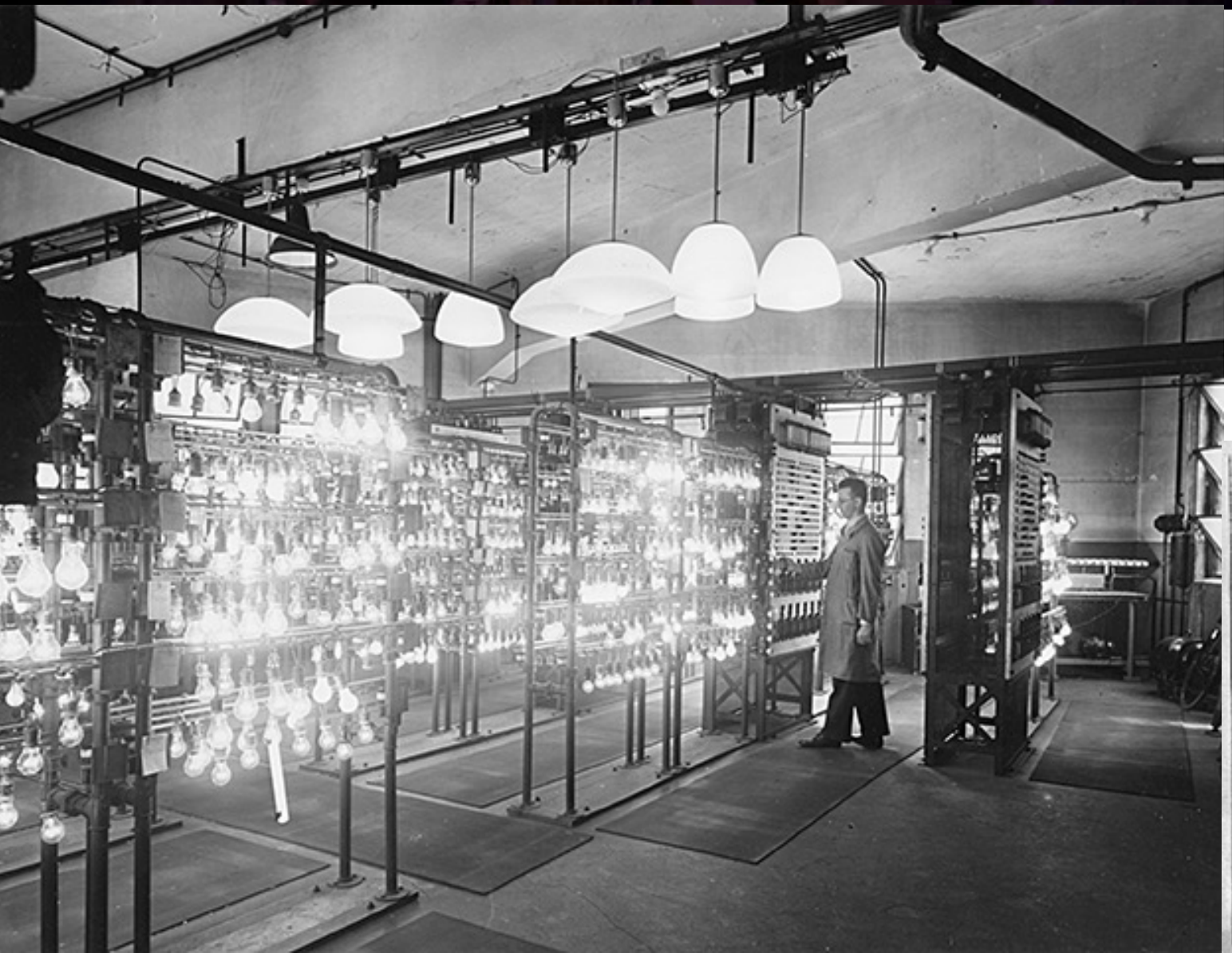
Fluorescent Tube
7-10% of power converts to light, But Still 40-50% Fixture efficiency Loss



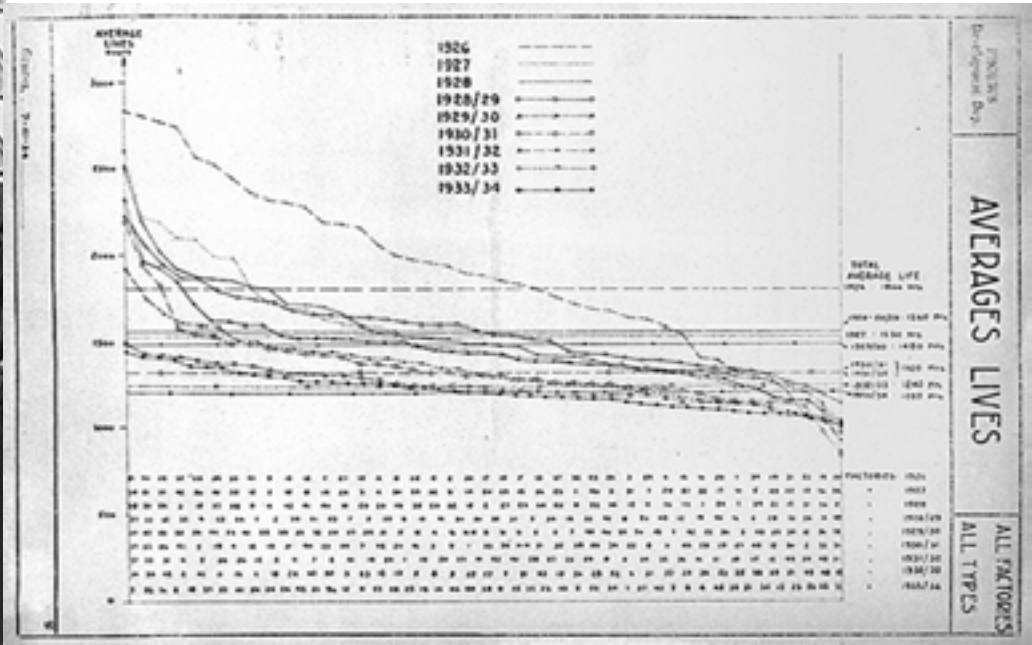
Packaged LED
Intrinsically Directional

3. Lifetimes of Lighting Systems

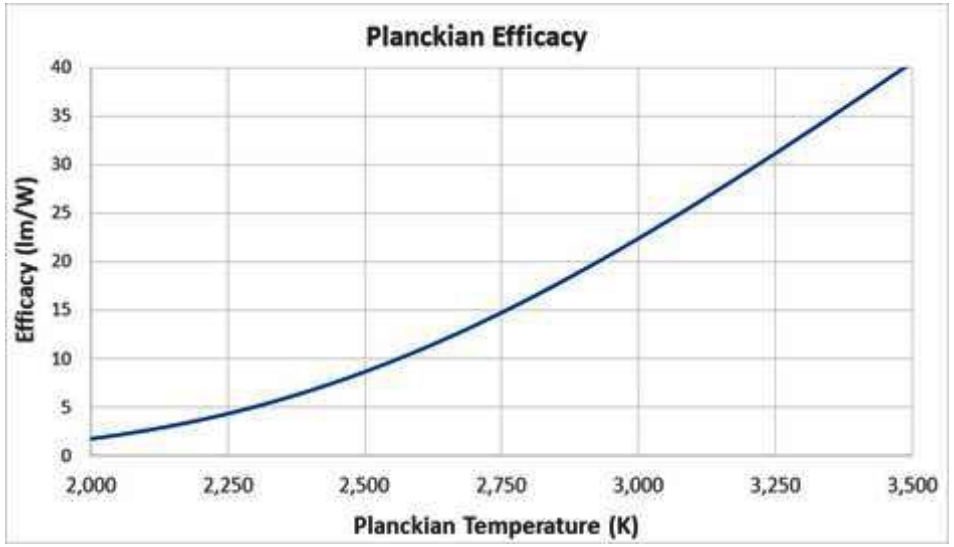
Planned Obsolescence- the Phoebus Cartel

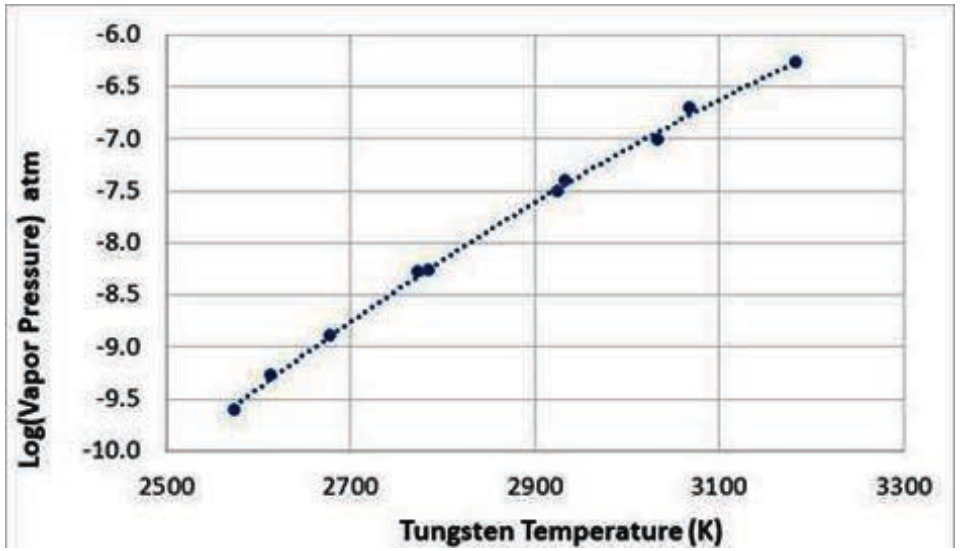


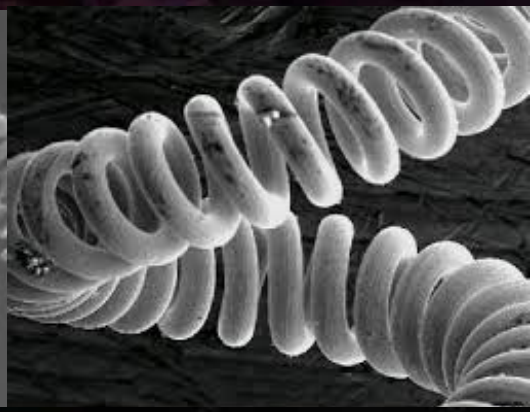
Max Lifetime: from 1500-2000 hrs To 1000 hrs

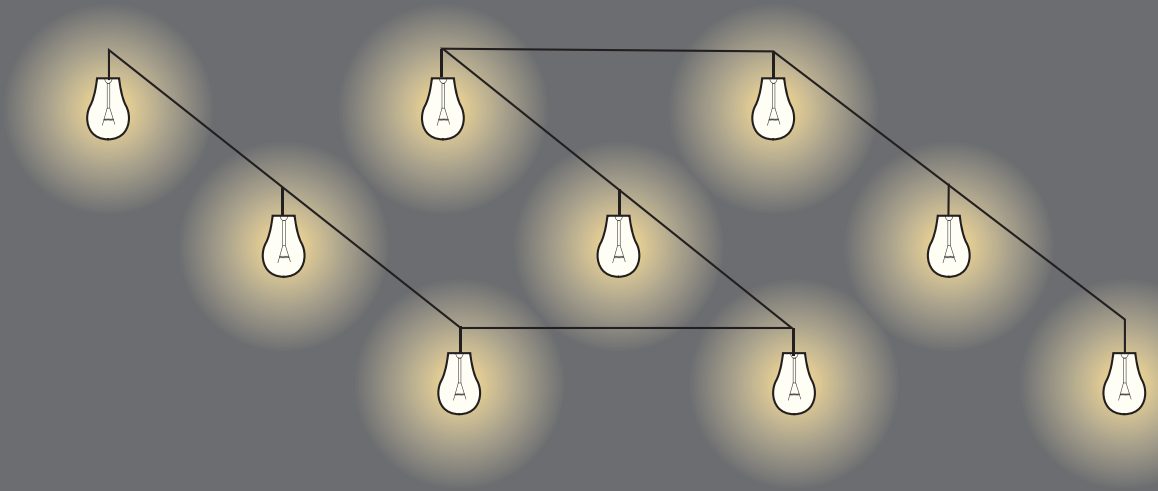


How Tungsten Lamps Fail

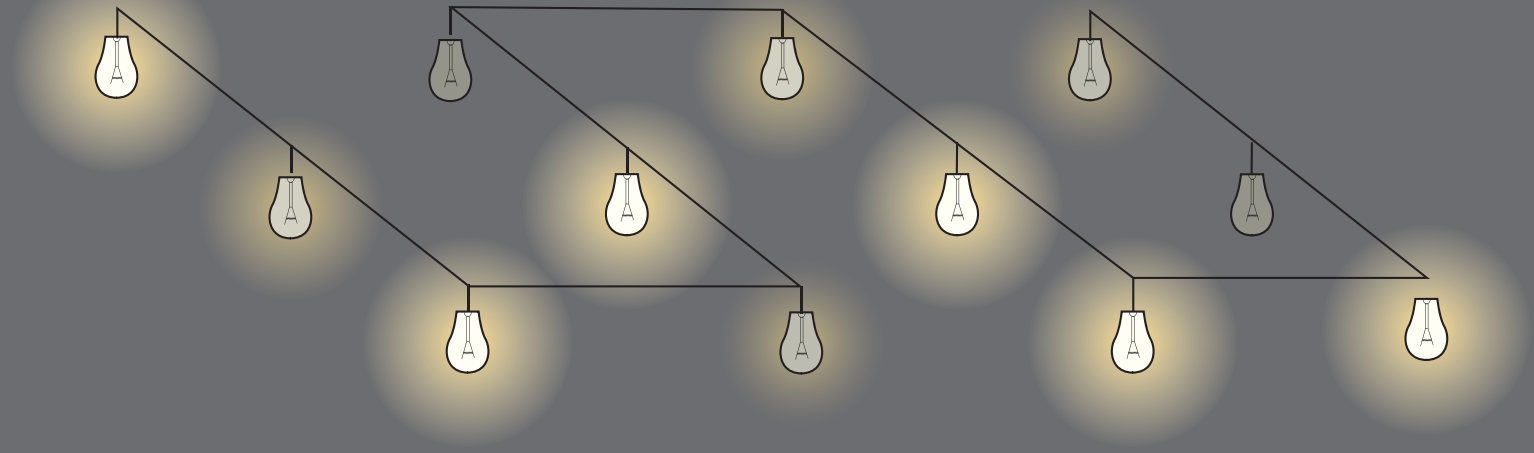








Fewer Shorter lifetime bulbs needed for given application



Longer lifetime bulbs less efficient, more prone to failure and lumen degradation

The Outlier: Centennial Bulb

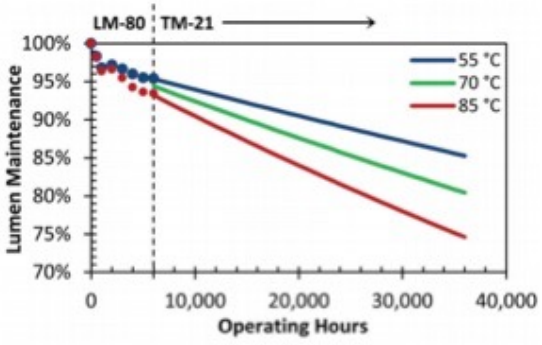
Made by Shelby Electric Company in late 1890s

Over 1 million hrs continuous use

Carbon Filament
45 lumens output

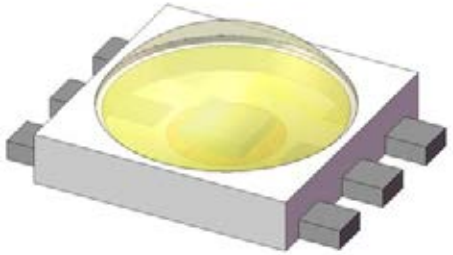
How LEDs Fail

Why LEDs Fail



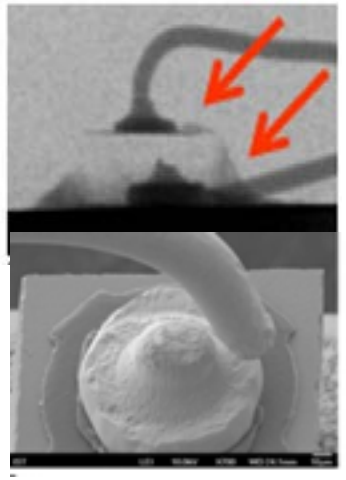
Lumen Degradation

Gradual fading vs catastrophic failure



Package

Phosphor & Silicone degradation

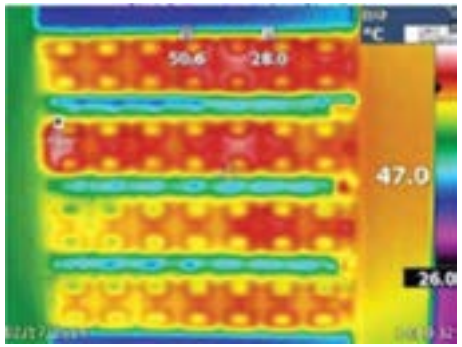


Electrical

ESD, broken connections

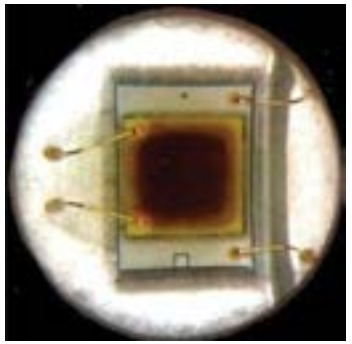
Color Shift

Inconsistent color between sources, unpleasant or undesired color



Thermal

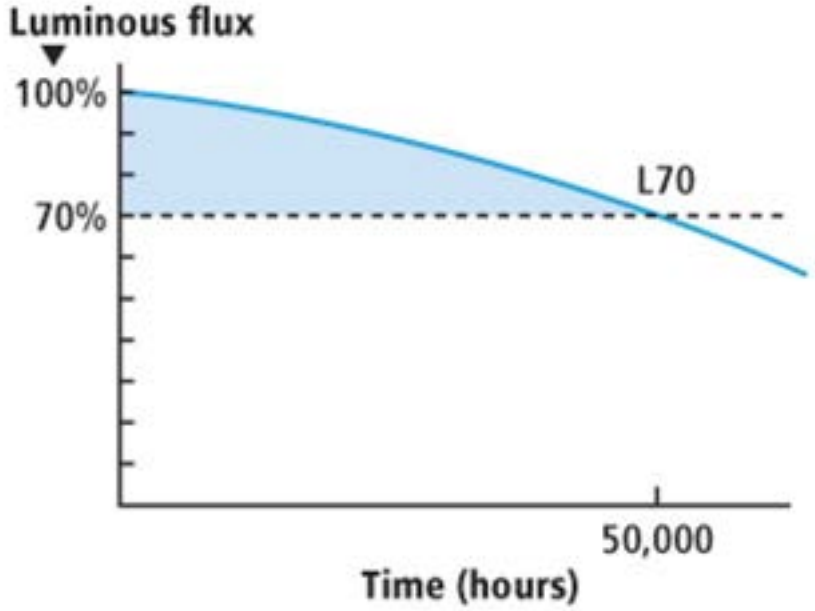
Inadequate heat sinking, Wrong Luminaire

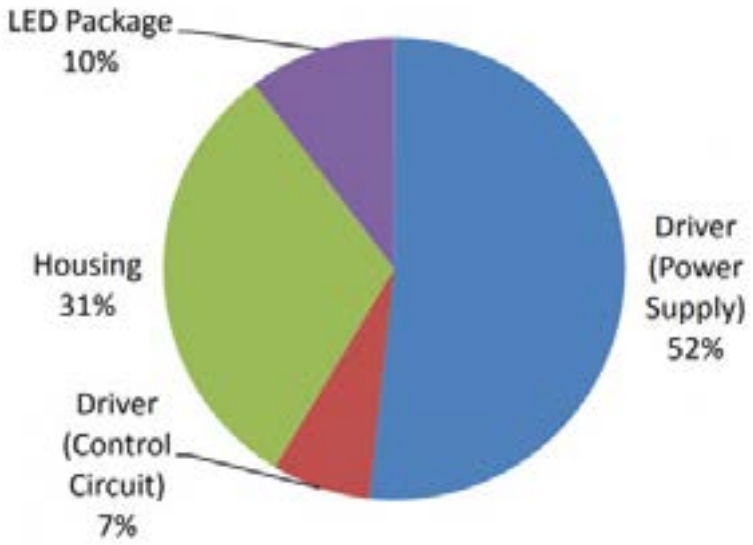


Chemical

VOCs
Discoloration

Luminaire Failure: Blame Almost Everything But the LED!





Lifetime Claims Hall of Shame

48” low bay fixtures
7-12,000 lm
Rugged housing, fully gasketed
IP rated
Calculated L70
> 300K+ hrs

3-22,000 lm
Two CCTs, low-ishCRI
Relatively long warranty
Lifetime: **L80F10 >200Khrs**
>200Khrs to L80 per IES TM-21

Variety of CCTs, 70 CRI
No mention of light output on cut sheet (?)
Power from 15 to 93 watts
IP rated
Light unit lumen maintenance L90B10C10
150K hrs

Cool white
12- 40,000 lm
Safety listed
IP rated for wet location
>250K hrs to L70

Lifetime Measurement

Methods

ANSI-IES LM80-15 provides methods for measurement of luminous flux for LED arrays, packages, and modules.

TM-21 establishes a standard way to use LM-80 data to make consistent lifetime projections beyond the testing period.

Since most manufacturers test for 6,000 or 10,000 hours, the accurate range based on TM-21 is up to 36,000 to 60,000 hours of useful life

IES Position Statement

PS-10-18

- IES standards do not support the use of marketing claims exceeding TM-21's 6X extrapolation limit…these are misleading.

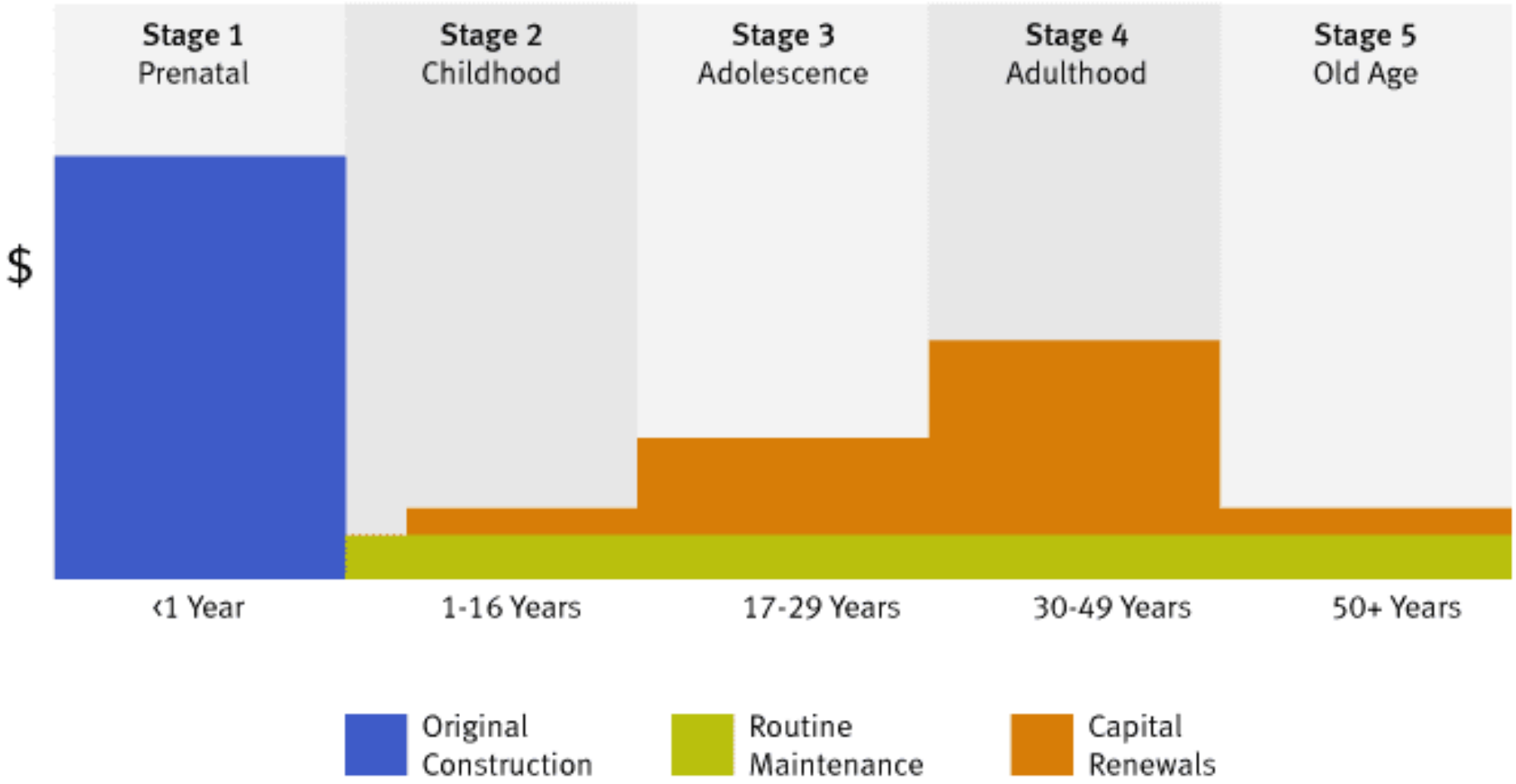
- The IES does not support the use of LED lumen maintenance life as the sole metric for determining solid-state luminaire lifetimes.

Alex Says So…

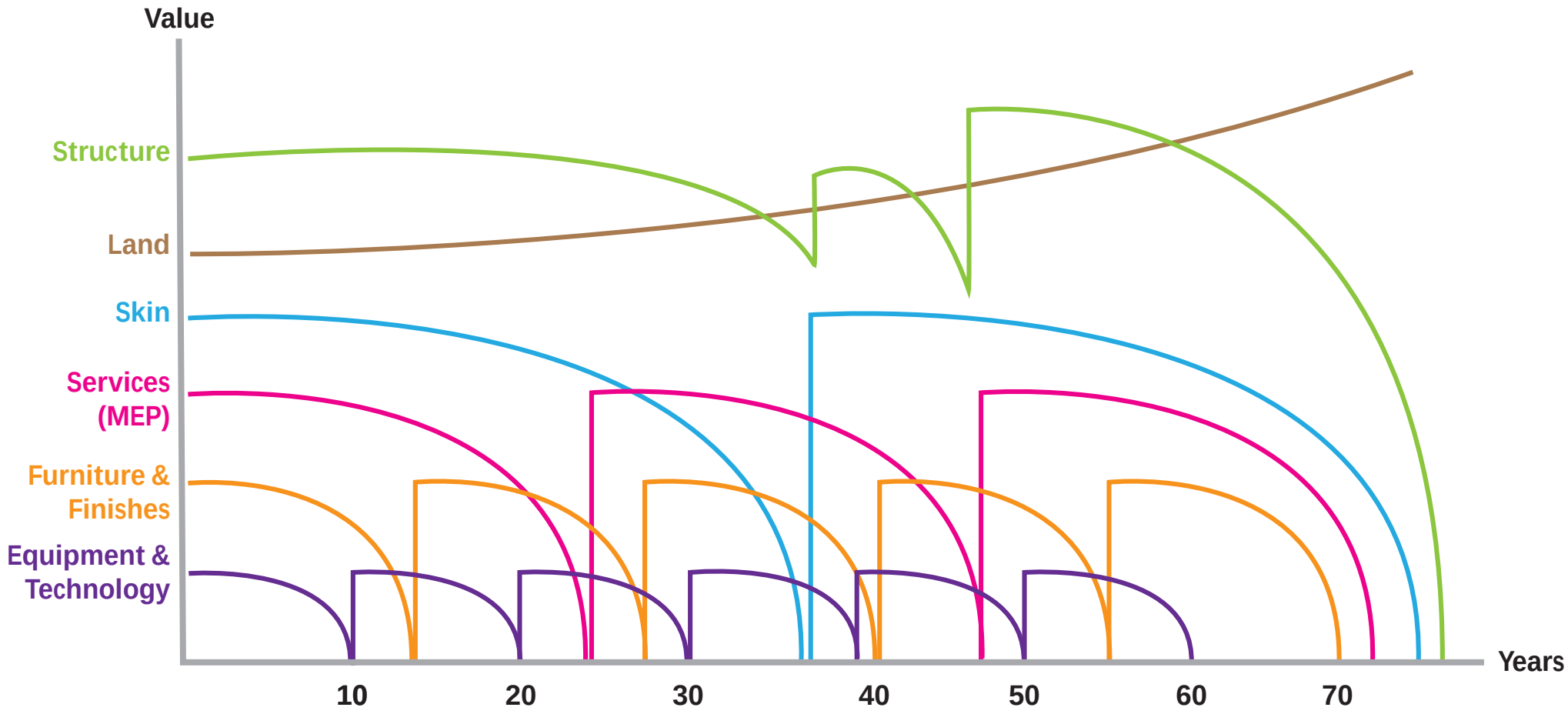

BESIDES- SSL technology is highly likely to evolve considerably by 25,000 hrs (5-10 years) in the future!

4. Building Lifetime & Cycles

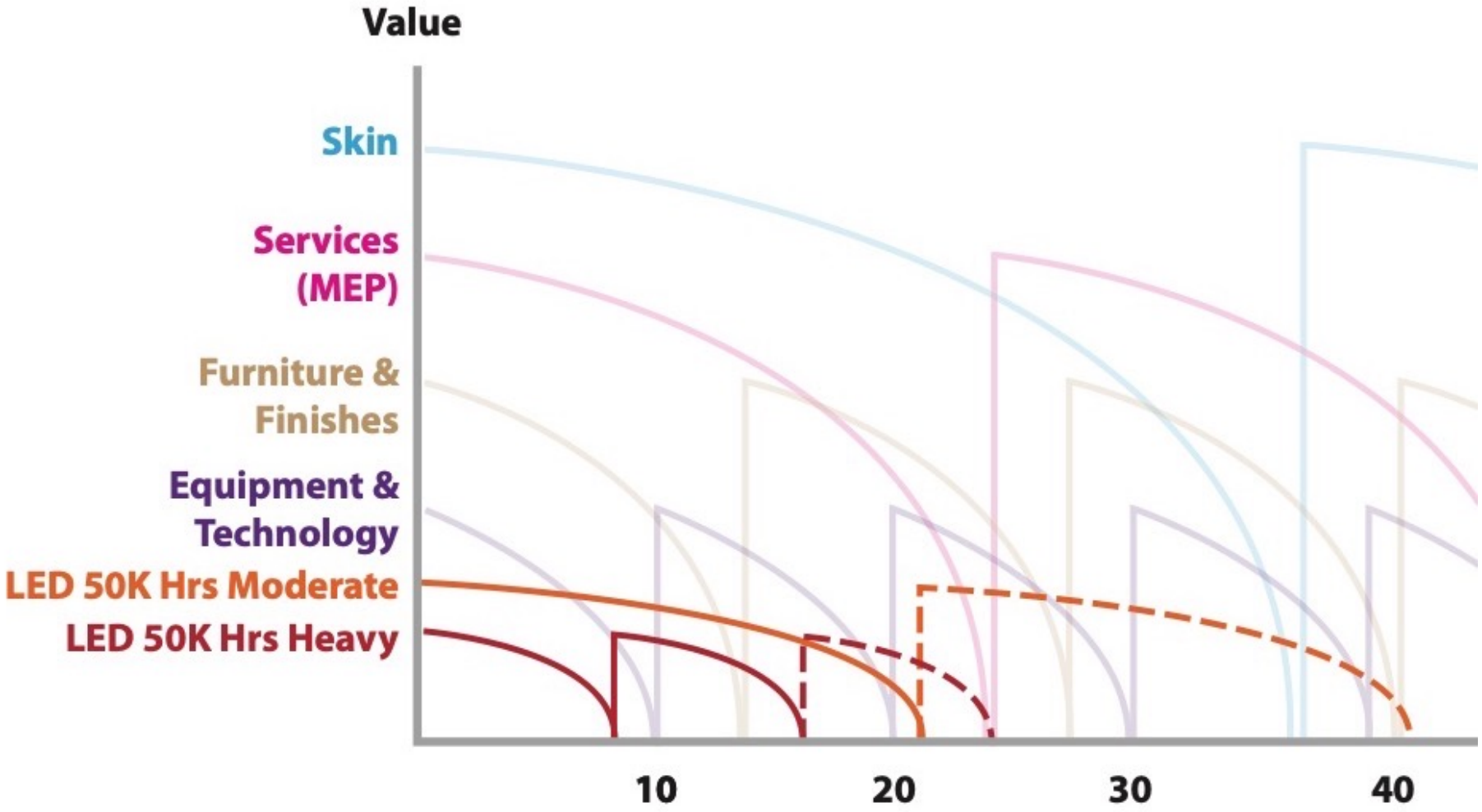
Renovation Cycles



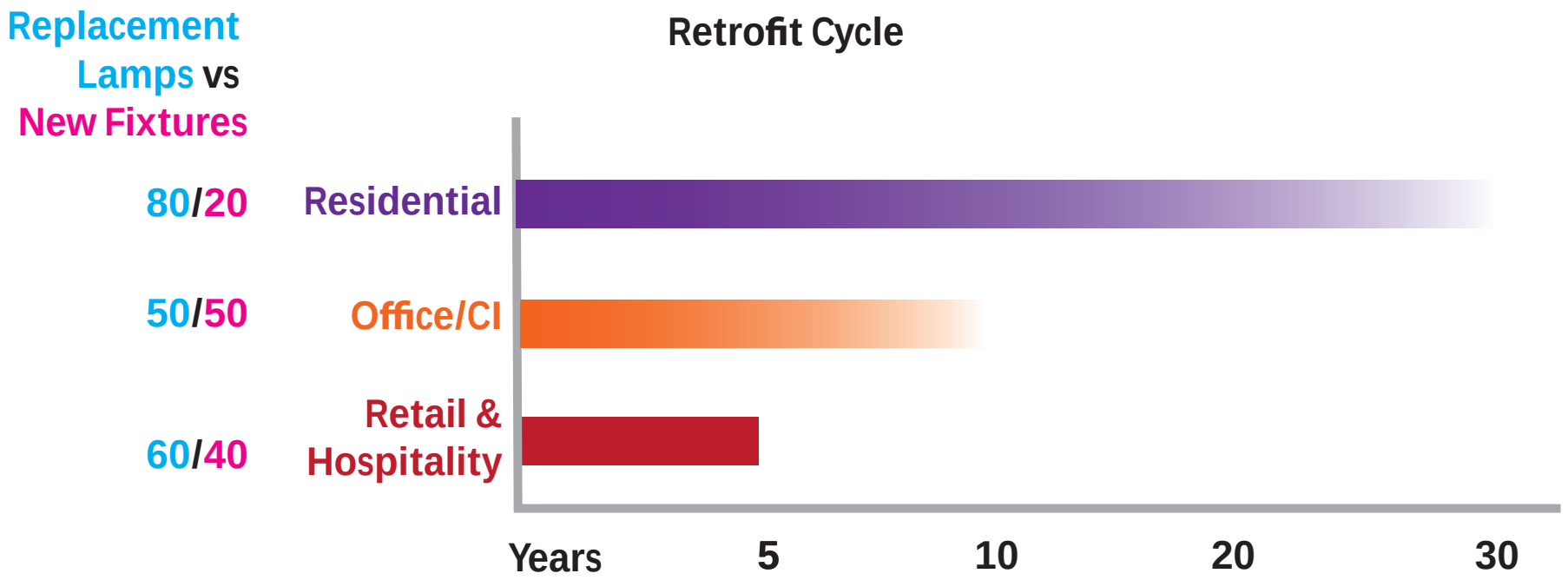
Building and Systems Lifetimes



Projected LED Lifetimes



Retrofit Choices



The Buying Decision

Rational ROI Calculations

Reduced maintenance

Energy Savings

Healthy, Happy, Productive Tenants

Higher Rents

3 Year payback

Rebates

Burn Hours per Year:	4380					
KwH Rate:	$0.15					
Commercial Fixture Type	Existing wattage	Annual Energy Costs (per Fixture)	Proposed LED Wattage	Annual Energy Costs (per fixture)	Annual Energy Savings (per fixture)	2015 Mass Save Retrofit Rebate
400W Metal Halide Area Light	455	$299.00	150	$99.00	$200.00	$200.00
250W Metal Halide Highbay	295	$194.00	125	$82.00	$112.00	$200.00
150W Metal Halide Wall Pack	190	$125.00	26	$17.00	$108.00	$100.00
32W 3 Lamp T8 2X4	107	$70.00	39	$26.00	$44.00	$85.00
32W 3 Lamp T8 Wrap	107	$70.00	50	$33.00	$37.00	$85.00
32W 2 Lamp T8 Vaportight	70	$46.00	30	$20.00	$26.00	$70.00

Emotional Decision Drivers

How long until it’s obsolete? 20 minutes?

Why would I want to upgrade a module that’s supposed to last for 50K hours?

Why install something with future capabilities no one understands yet?

What’s Arcadian lighting?

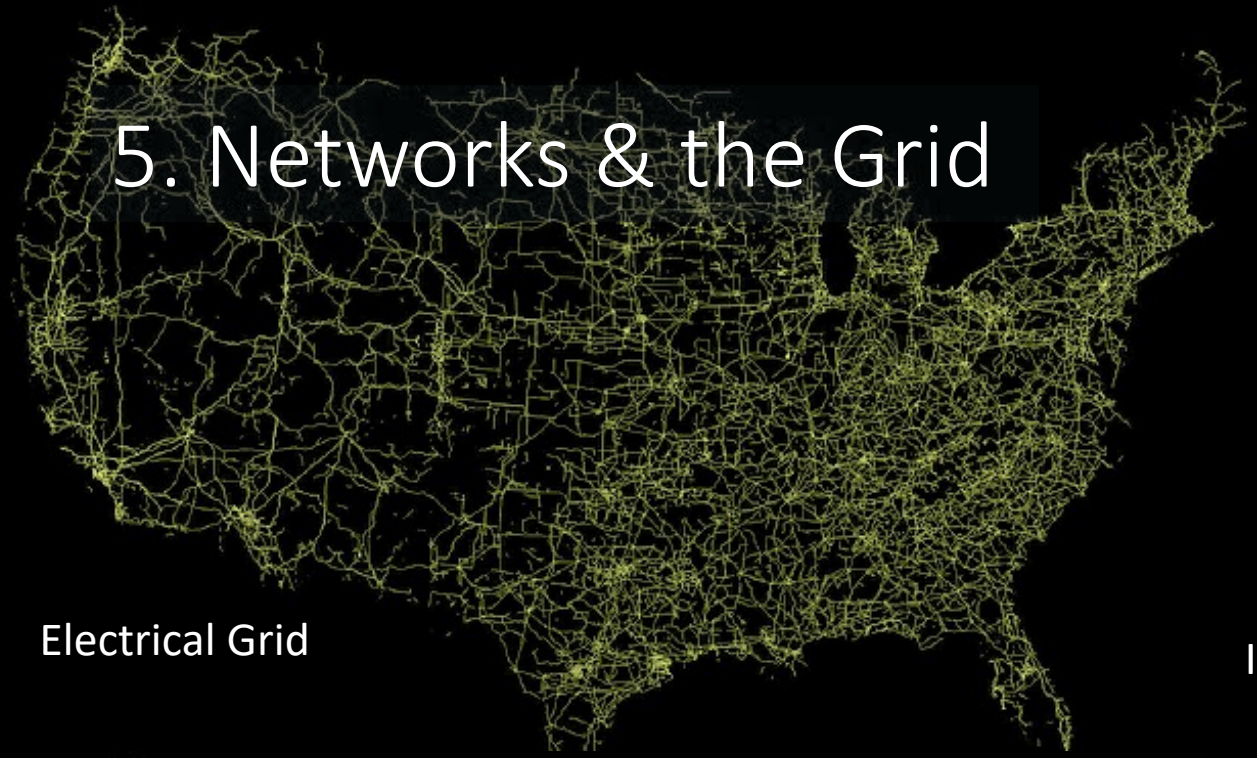
I don’t care about energy anymore!

What, I need an IT guy to run the lights?

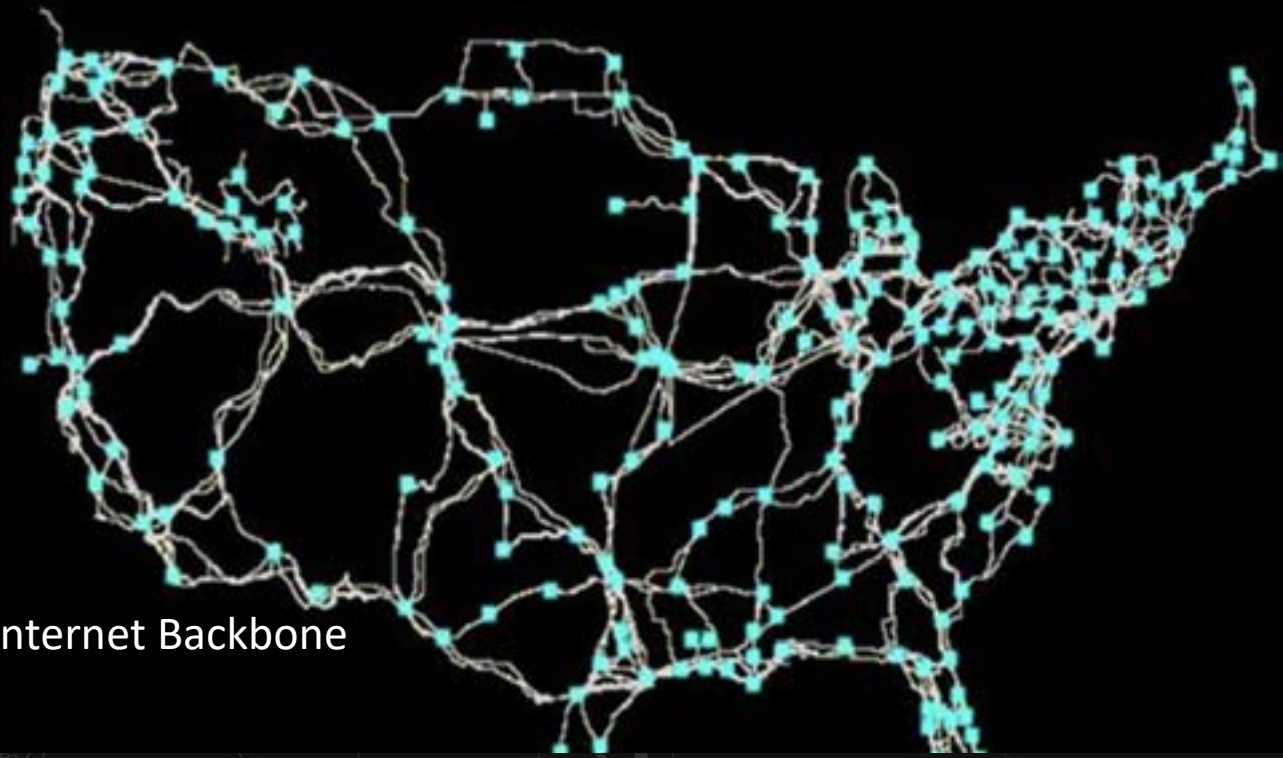
Who owns the data again?

Too many choices, we’re going to delay the project.

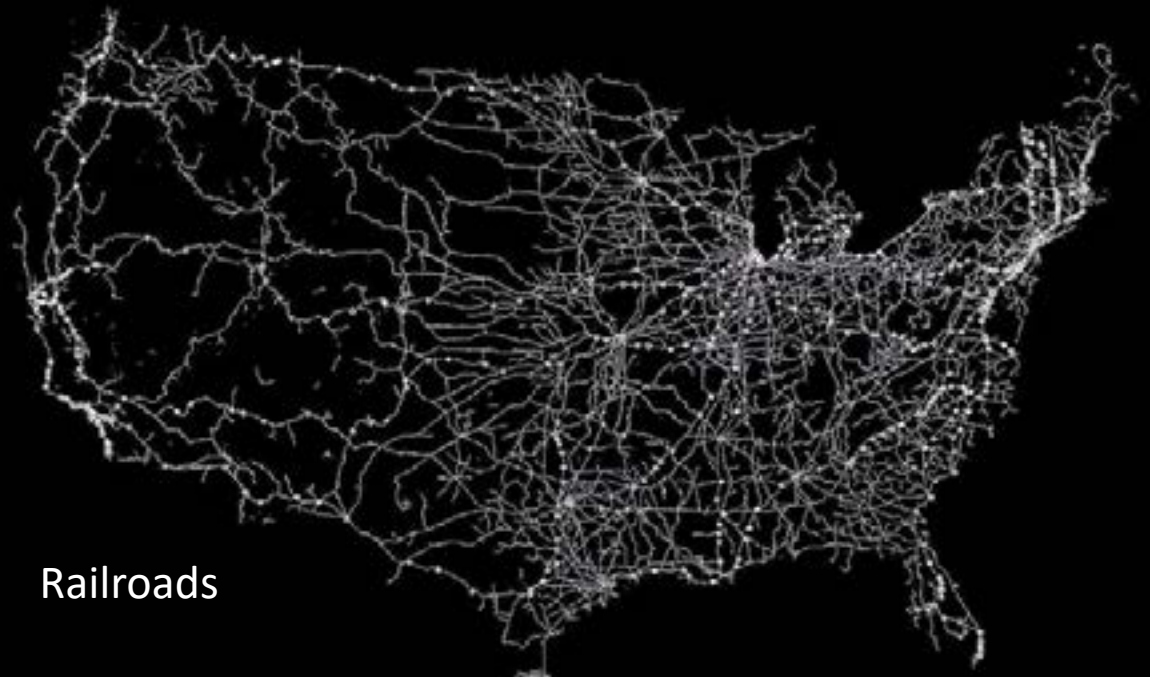
5. Networks & the Grid



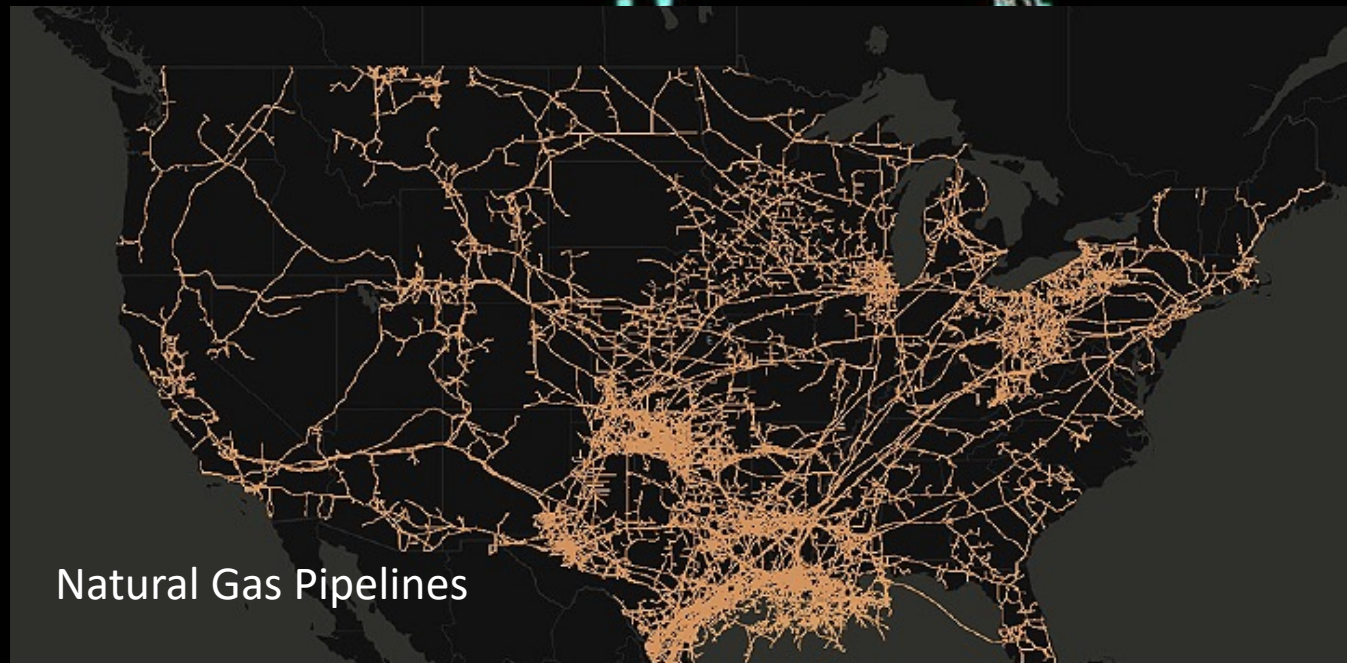
Electrical Grid



Internet Backbone



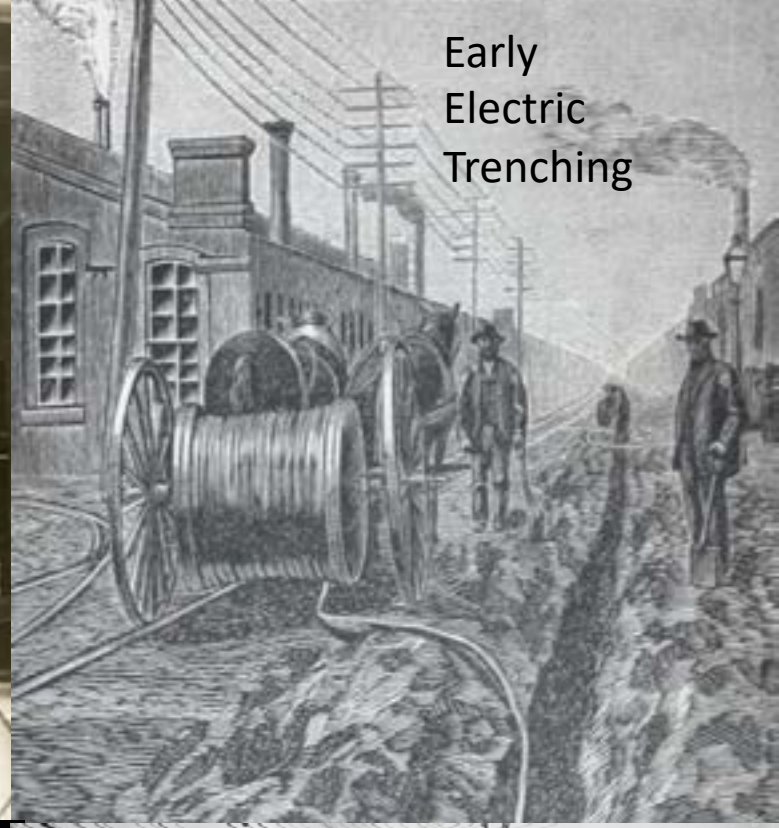
Railroads



Natural Gas Pipelines

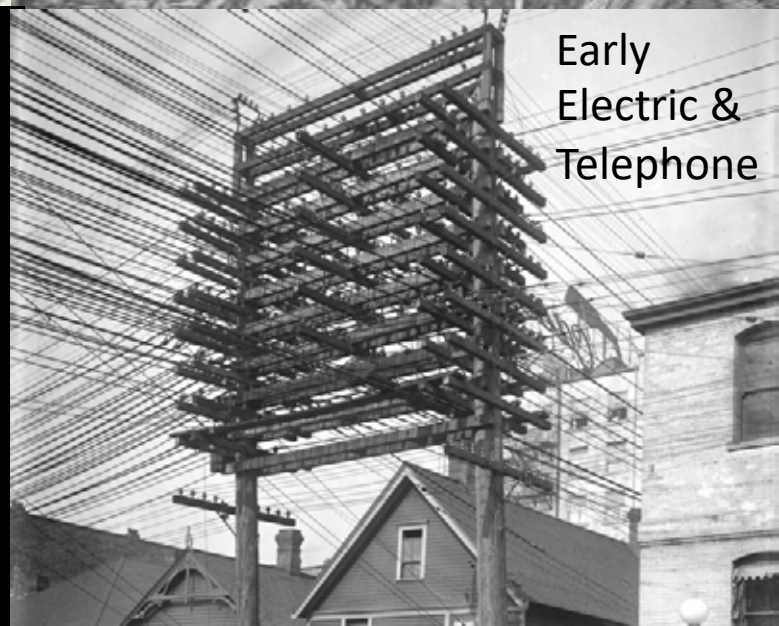
Gas

Early
Electric
Trenching

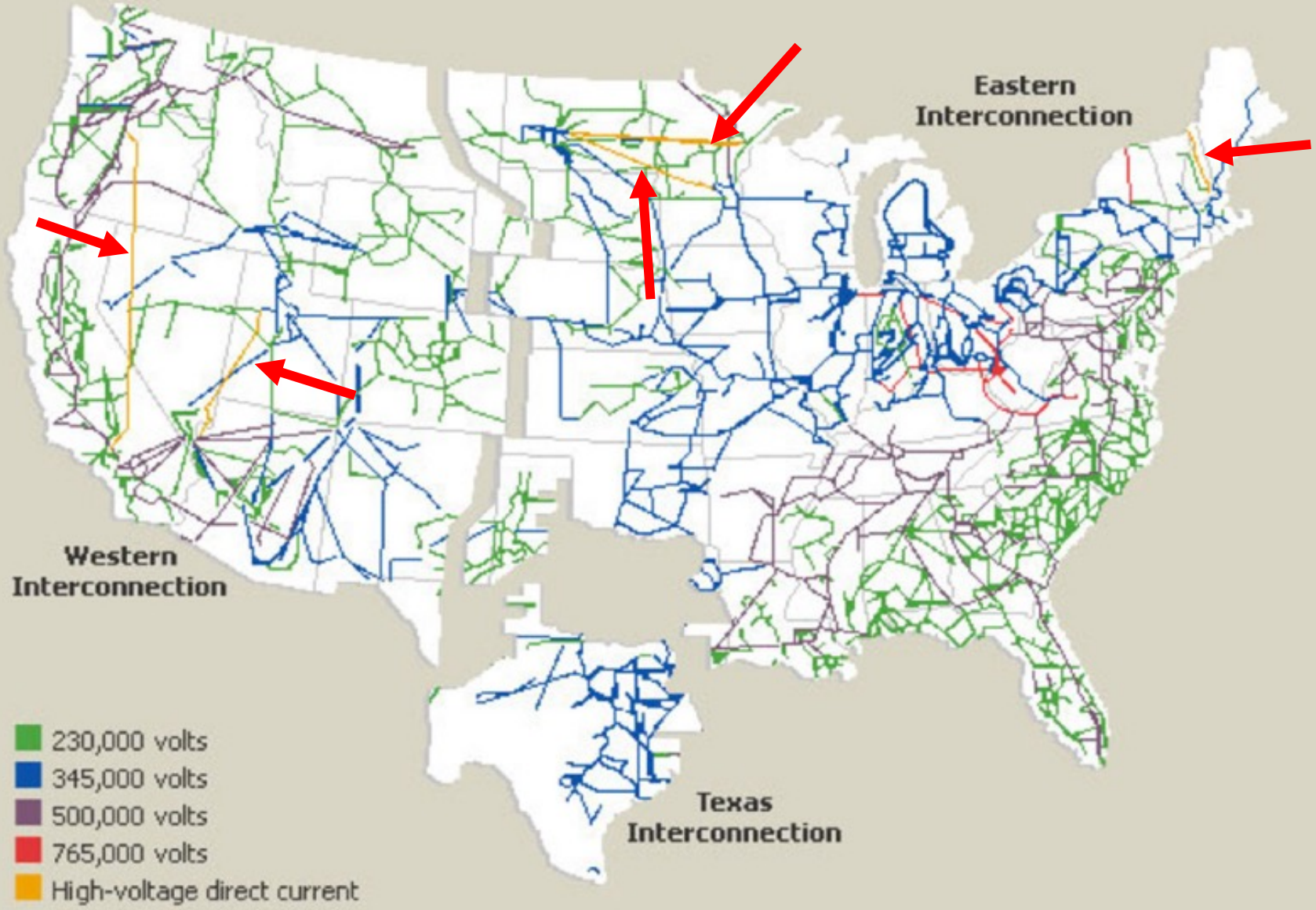


Water

Early
Electric &
Telephone



A Monumental Patchwork



The Grid is More Than a Bunch of Wires

Infrastructure

Political System

Economic System

Cultural & Social System

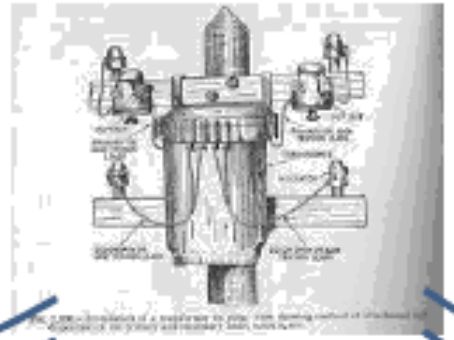
Legal System

Information System

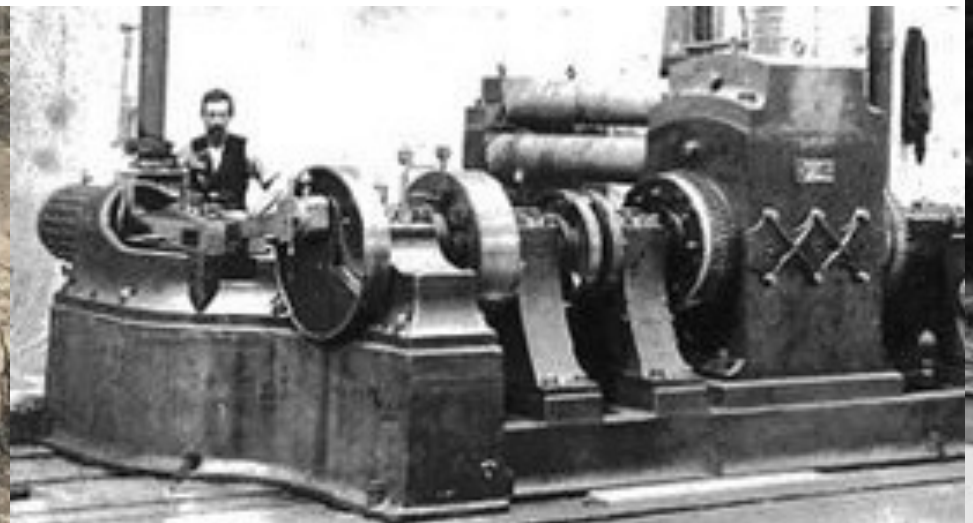
First Grids: Whole Systems

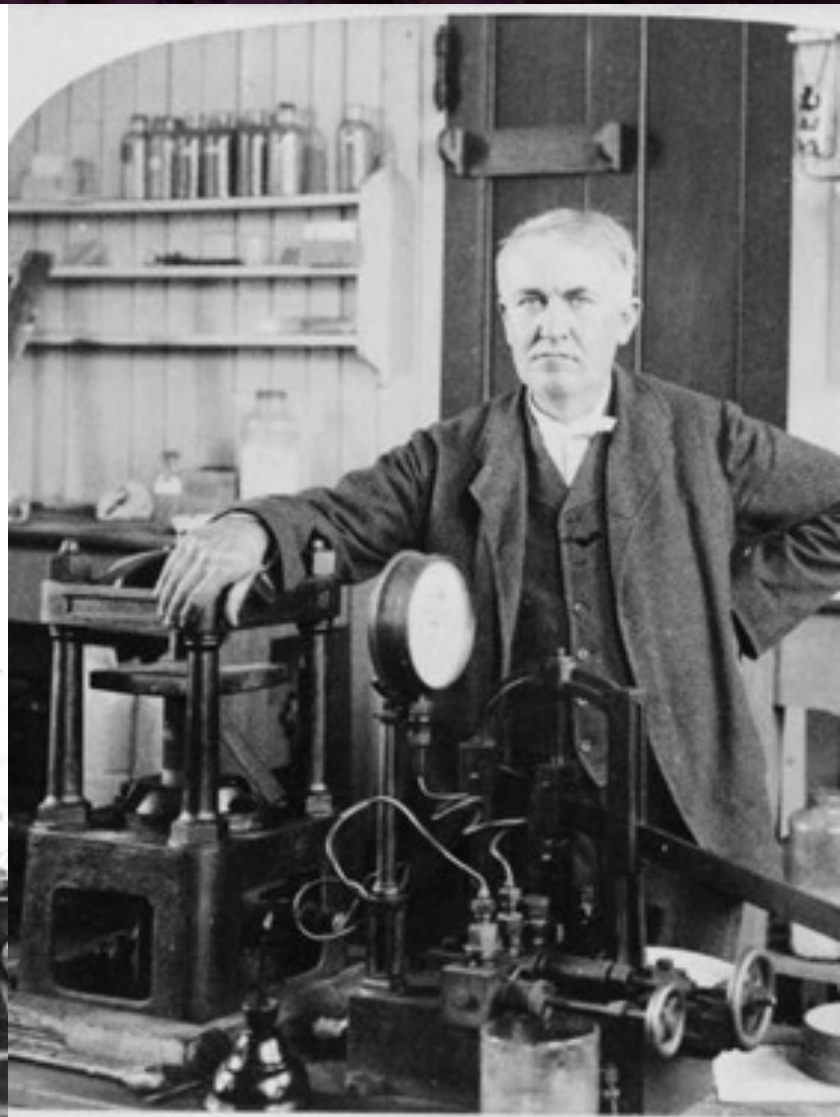
Pearl Street Station

electric pole



electric light





most famous Inventor of the Age—Thos. A. Edison in his Laboratory,

6. The Good Old Days

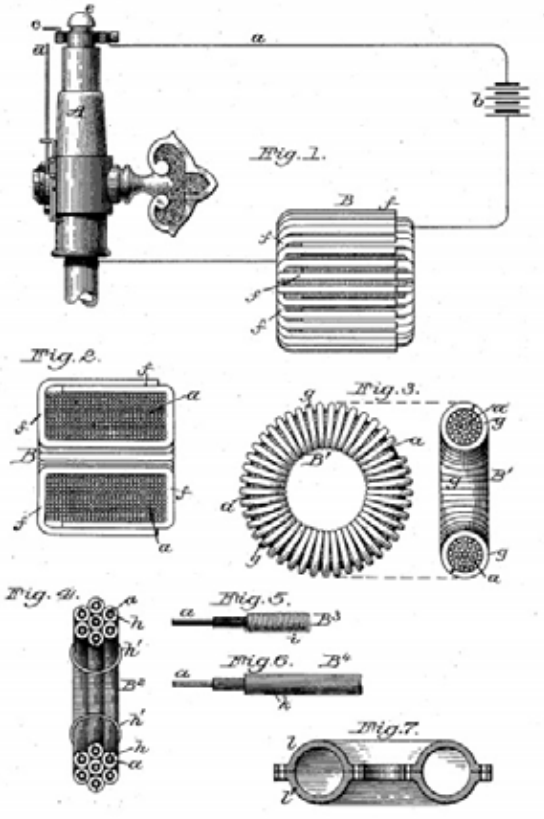
Gas Evolves, then Lingers…

(No Model.)

R. EICKEMEYER.

SPARKER COIL FOR GAS LIGHTING.

No. 375,614. Patented Dec. 27, 1887.



Witnesses:
Philip F. Garner.
Howell Battle

Inventor:
Rudolf Eickemeyer.
By Wm. Elwood
Attorney.

Welsbach
LIGHT
Inverted Arc Lamp, Fig. 623.

Storm Proof—
For Exterior Lighting.

BRITISH MADE.

Welsbach-Kern
(Patent) Inverted System

BRITISH MADE.

Height over all.

1-light	1 ft. 2 ins.
2-light	2 ft. 4 ins.
3-light	2 ft. 4 ins.
4-light	2 ft. 7 ins.

Width over all.

1-light	1 ft. 1 in.
2-light	1 ft. 7 ins.
3-light	1 ft. 3 ins.
4-light	1 ft. 8 ins.

Fig. 623. Three Light.

ENAMELLED Green Steel Casing, fitted with Welsbach-Kern Inverted Burners, Gas and Air Regulators operated from outside. Sliding Door to give access to Burners for cleaning purposes. Fitted with Magnesia Nozzles, Welsbach Mantles, and Glass Mantle Protectors. Complete as shown. Highly efficient and regenerative.

	Size per hour.	C.P.	Price.	Carriage Extra.
1-light	4 feet	115	30/-	5/- extra.
2-light	8 feet	260	47/6	6/- extra.
3-light	12 feet	400	52/6	6/- extra.
4-light	16 feet	530	72/6	9/- extra.

All on or off, or One light on and the rest off, 7/6 per Lamp extra. Cup and Ball, 3/6 per Lamp extra.

RENEWALS.

Glass Mantle Protectors (Fig. 623) 3/4½ per dozen, or in case lots of 3 gross, 33/- per gross.

	1-Light.	2-Light.	3-Light.	4-Light.		1-Light.	2-Light.	3-Light.	4-Light.
Clear Glass Globes, each	2/3	5/9	5/9	6/-	Wired Globes, extra each	2/-	2/-	2/9	3/6
" " " per dozen	19/6	57/9	57/9	93/-	Parabolic Reflector, extra	3/6	6/-	7/6	
Case contains	12	12	12	12	Welsbach Mantles, 4½d. each, or 4/- 5d. per dozen subject as usual.				

The Welsbach Mantles for Upright lighting are "C," "CX," and "Flaisnetty," price 4½d. each.

THE WELSBACH INCANDESCENT GAS LIGHT CO., LTD.,
Welsbach House, 344-354, Gray's Inn Road, London, W.C.

Retro Nostalgia

MAIA (MAOA? MABA?)

OWN THE LIBS!

6-PAK searing hot, energy inefficient, super bright incandescent light bulbs 100% Made in the USA, hand blown by patriotic conservatives!

FREEDOM BULBS

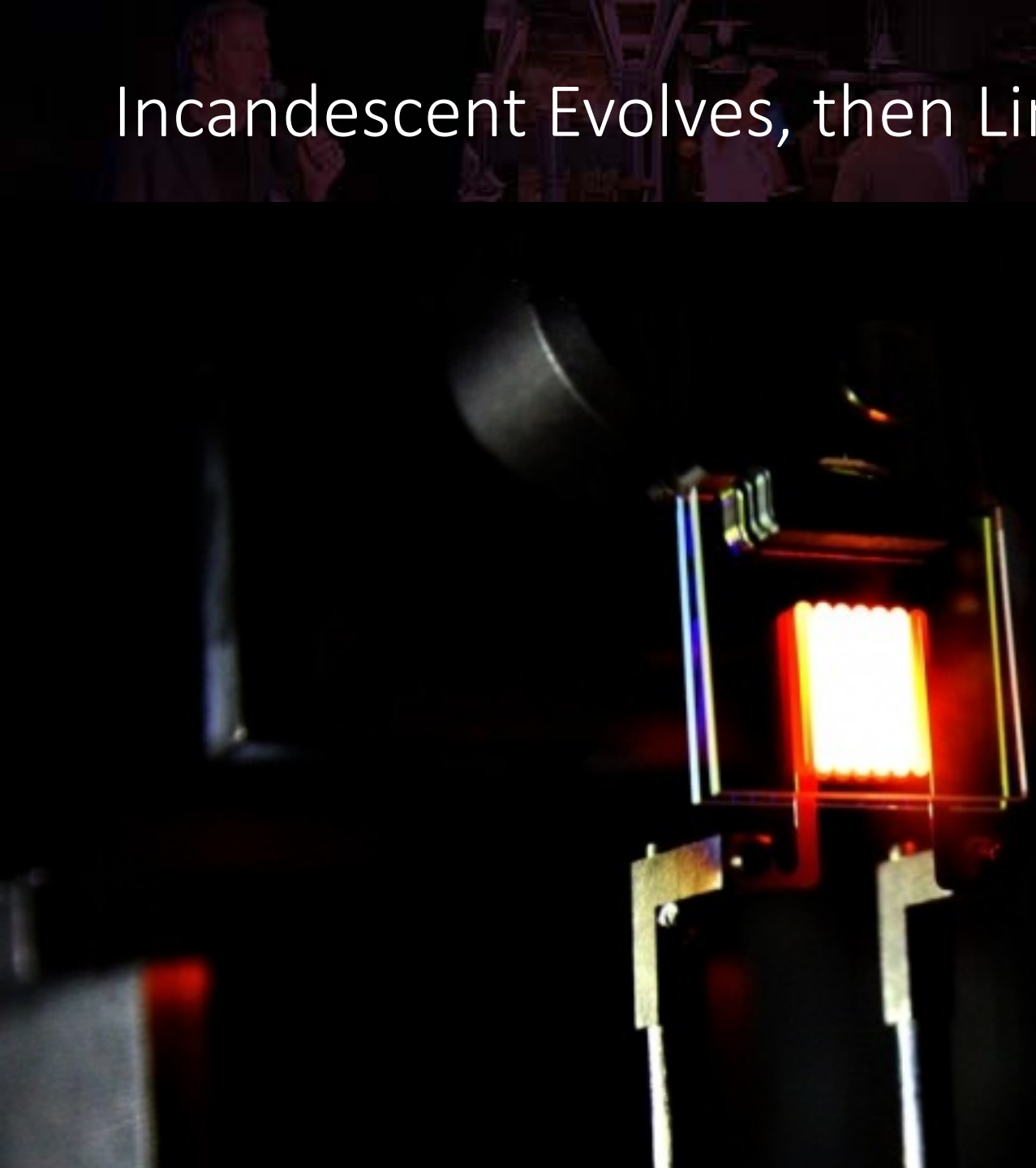
Make America Bright Again!

- Replace those LED hippie bulbs!
- NO Energy Star rating!
- Cause neighborhood brownouts!
- Energy bill increase guaranteed!

IN YOUR FACE ECOFASCISTS! IN YOUR FACE UN AGENDA 2030!

IN YOUR FACE OBAMA!

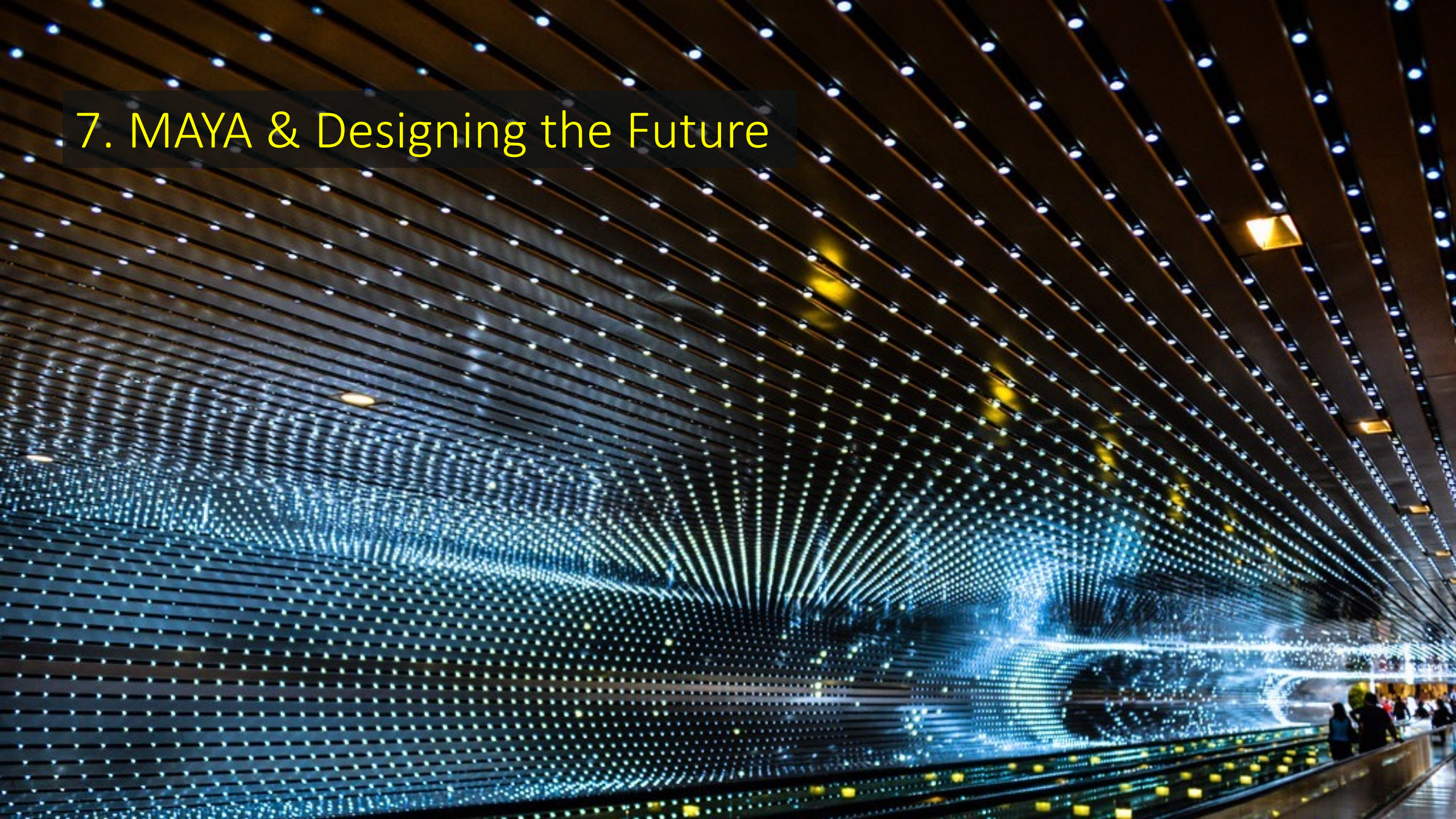
Incandescent Evolves, then Lingers?



Nanophotonic Fabulousness

Jan 2016: Researcers at MIT develop advanced incandescent using a traditional heated filament with “light recycling” enabled by an a photonic crystal material. Efficiency is demonstrated at 6.6%, with potential for 40% efficiency.

7. MAYA & Designing the Future

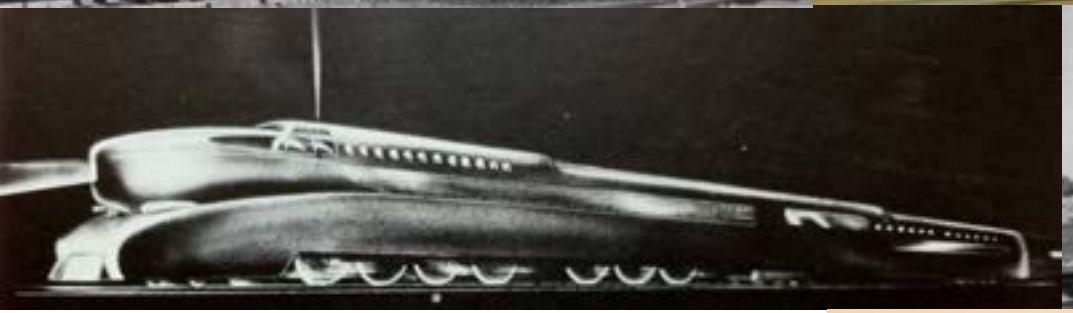


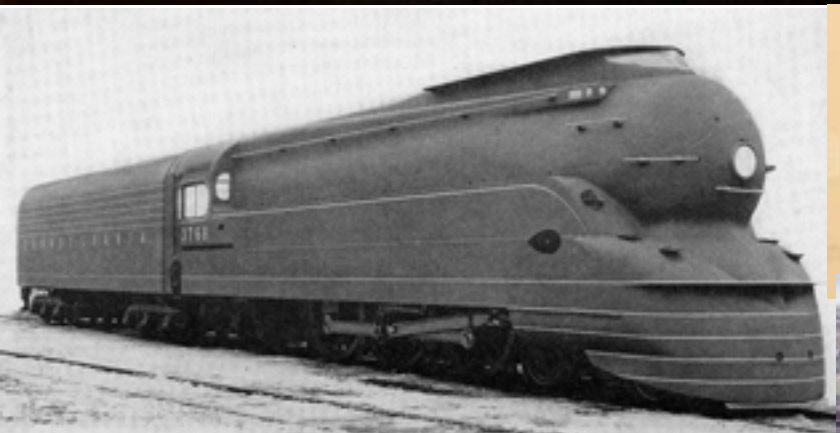
Raymond Loewy: Design GoDaddy of the 20th Century

MAYA: Most Advanced Yet Acceptable

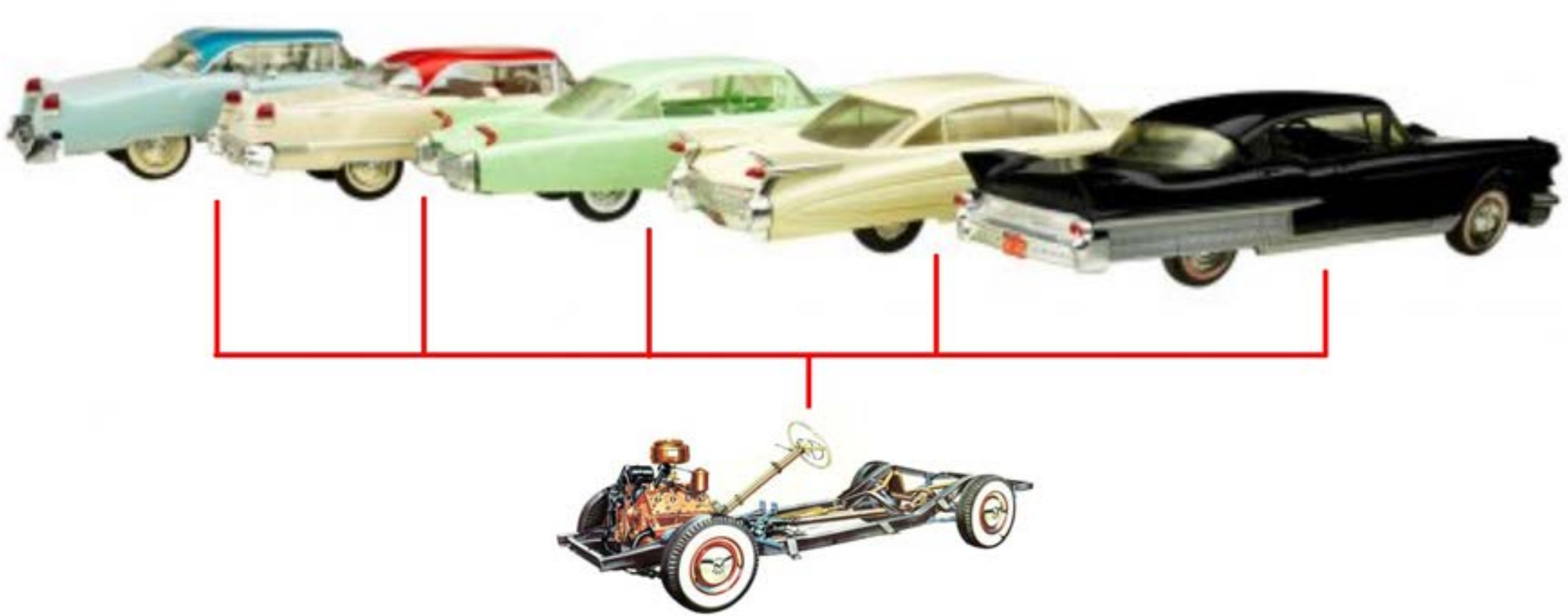





Planned Obsolescence As Design Paradigm

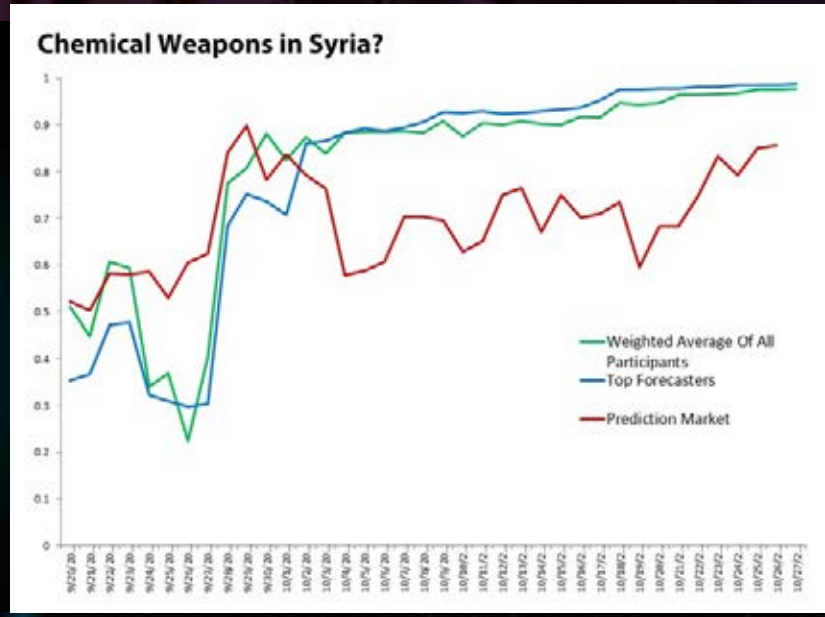


How many designers does it take to change the lightbulb?

Does it Have to Be a Lightbulb?

Reimagine the Connections!

8. Prophecy, Prediction, & Scenarios

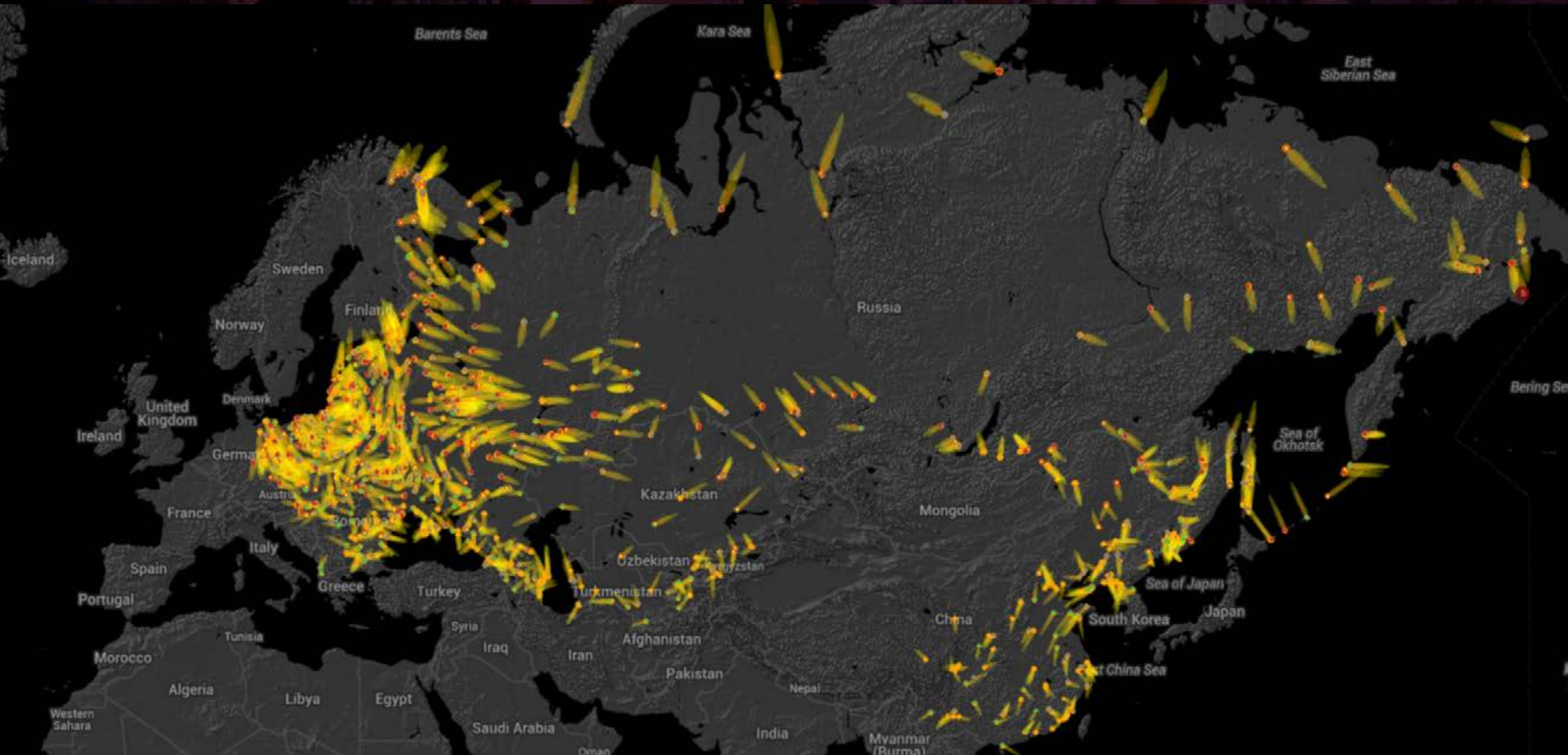


A Grain of Evidence

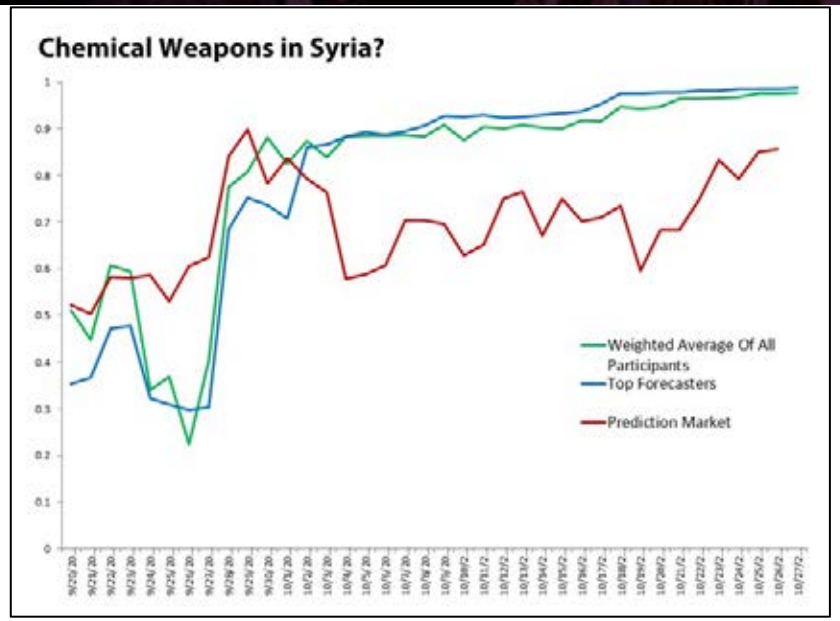
Haruspicy: Reading of Entrails, per Vitruvius

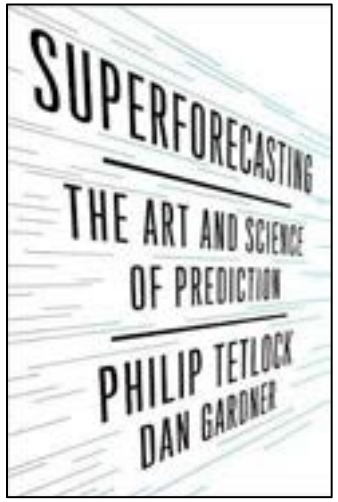
Psychics: Trained to body language & other Unconscious data

Cold War Nuclear Strike Scenarios



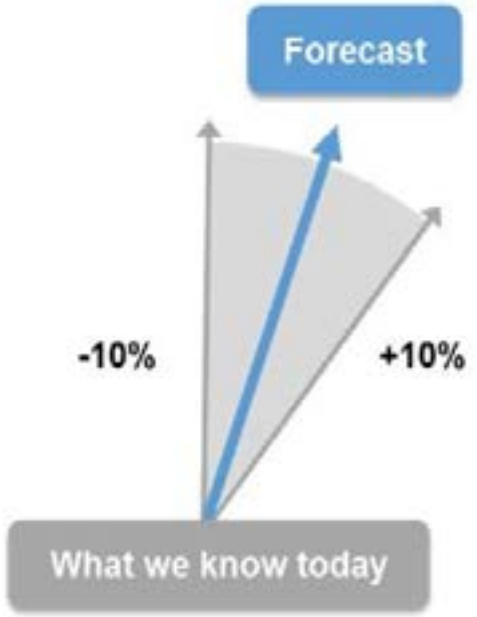
Forecasting & Scenario Planning





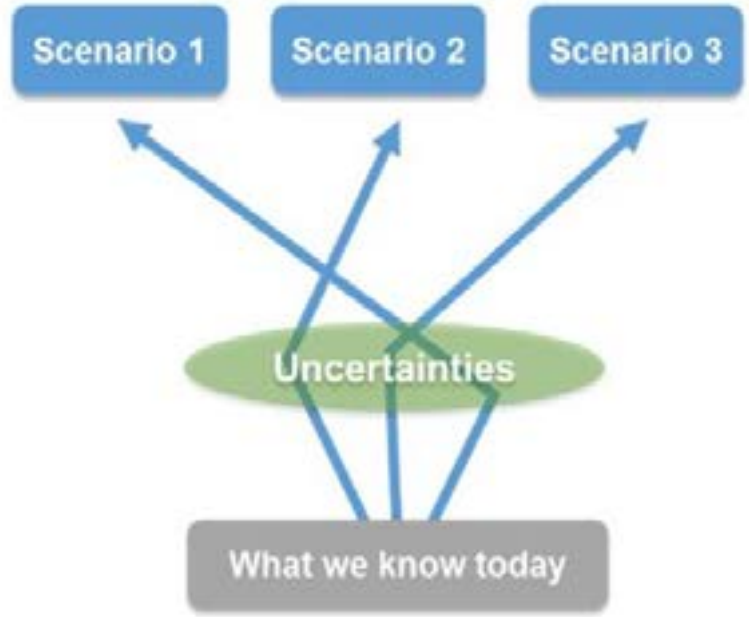
Forecast Planning

Extrapolating from the Recent Past

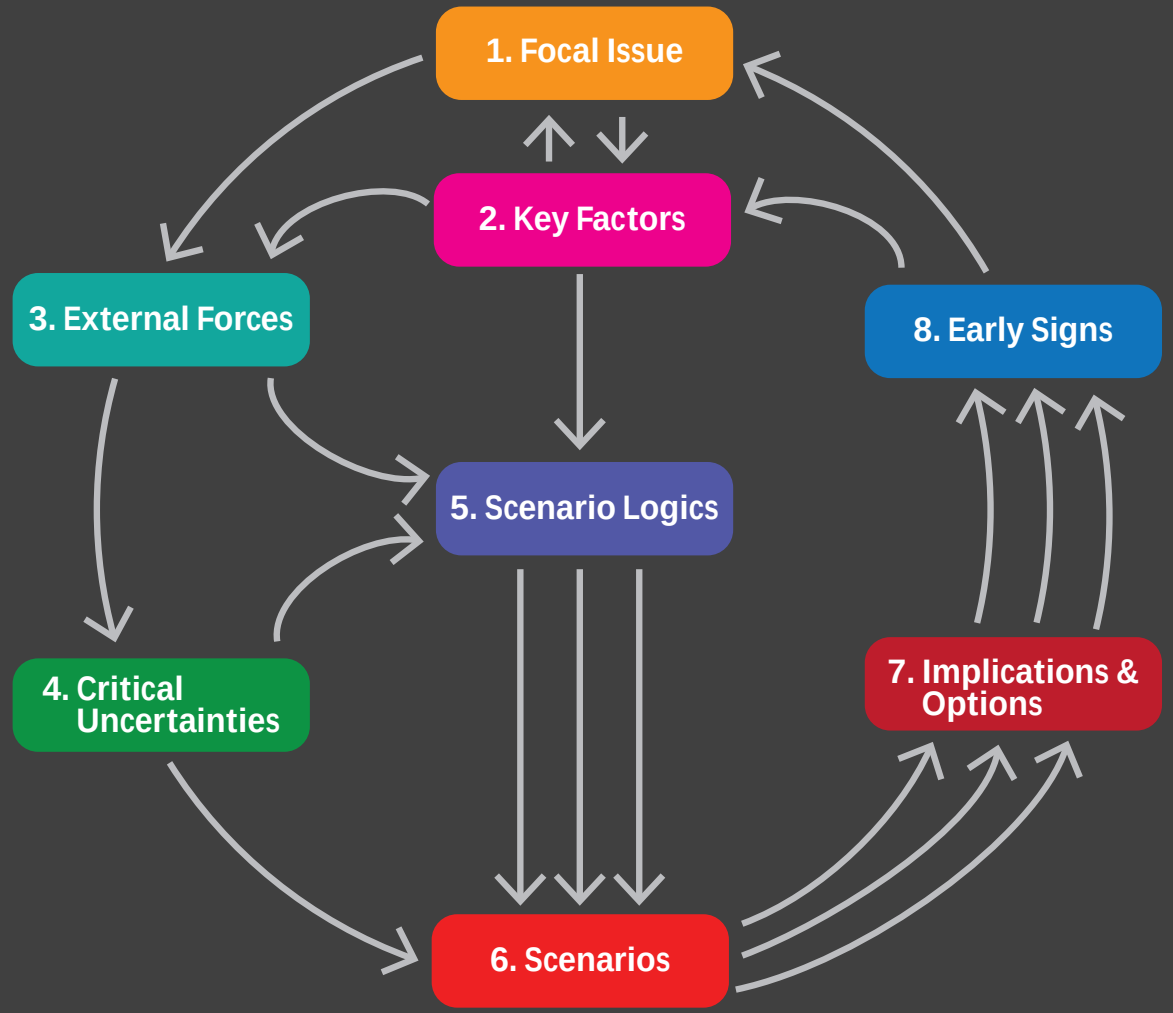


Scenario Planning

Envisioning Multiple Futures

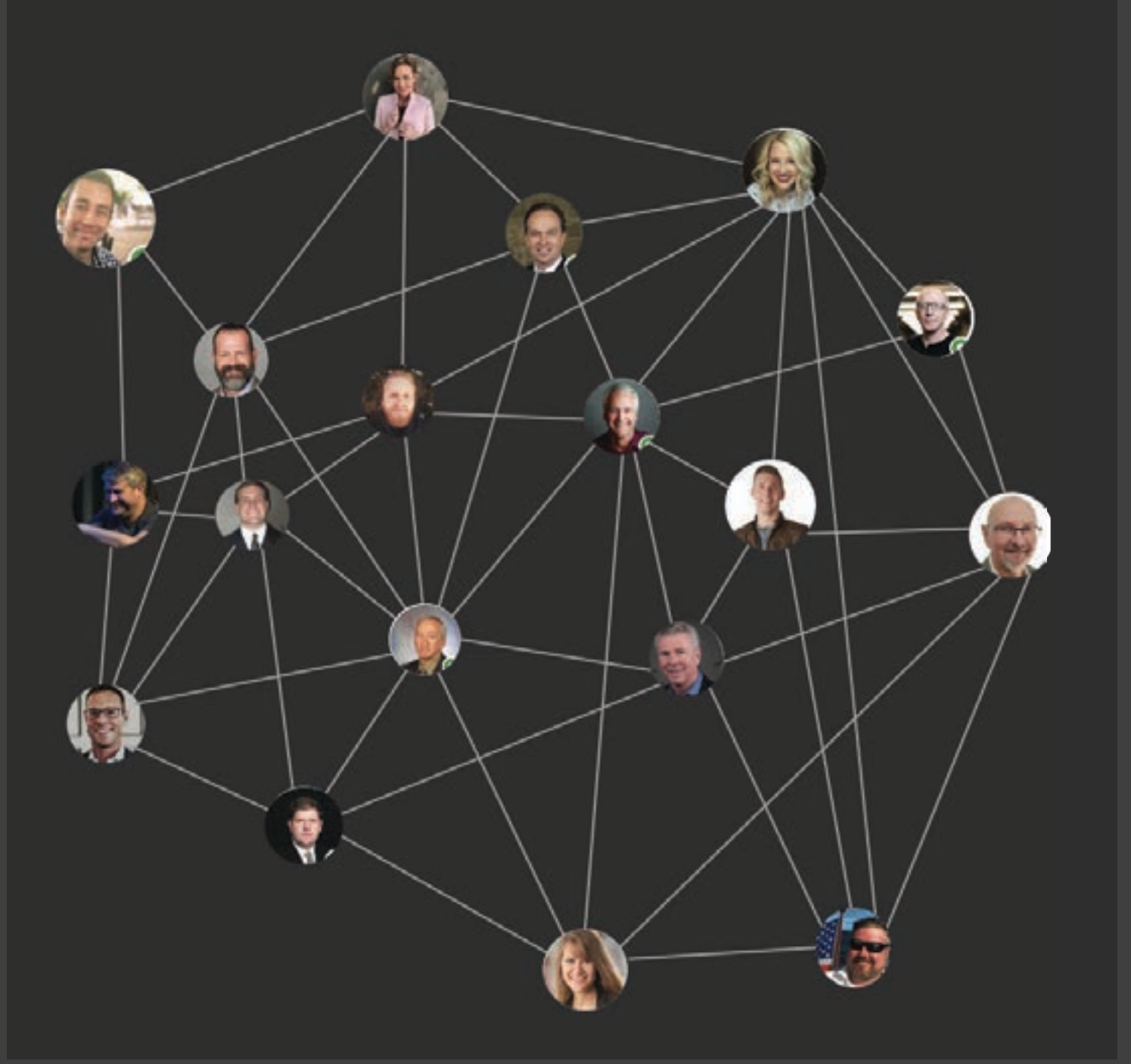


The Scenario Planning Process

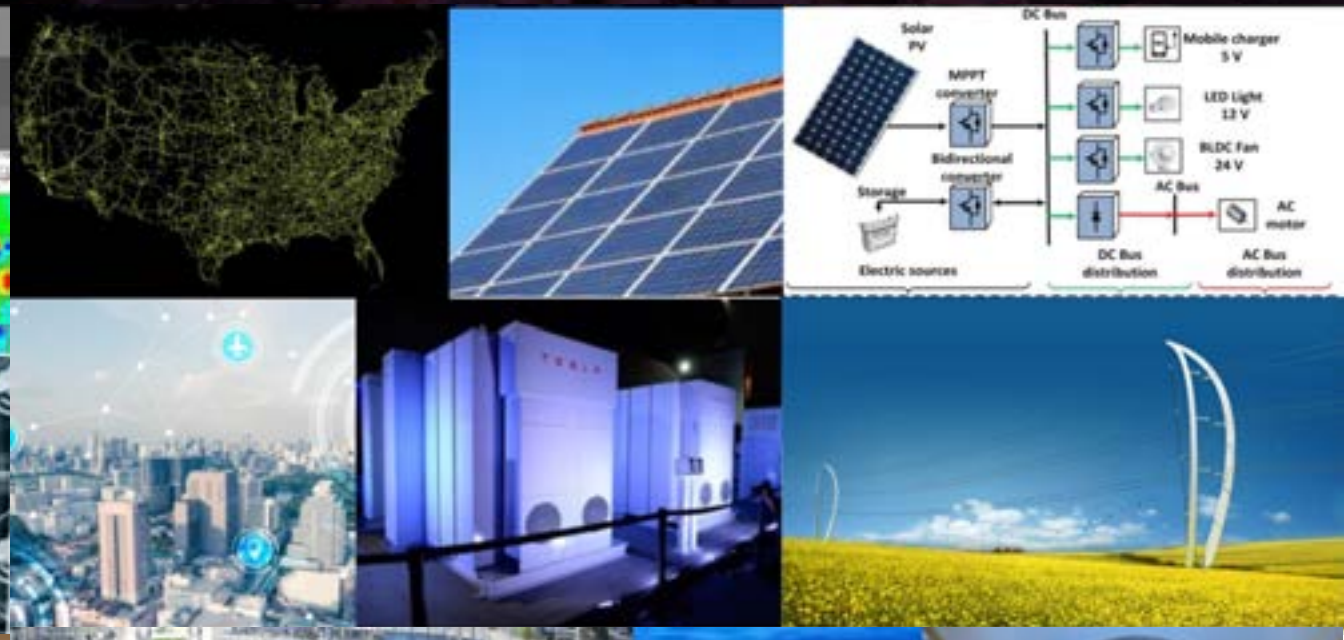


The Scenario Engine

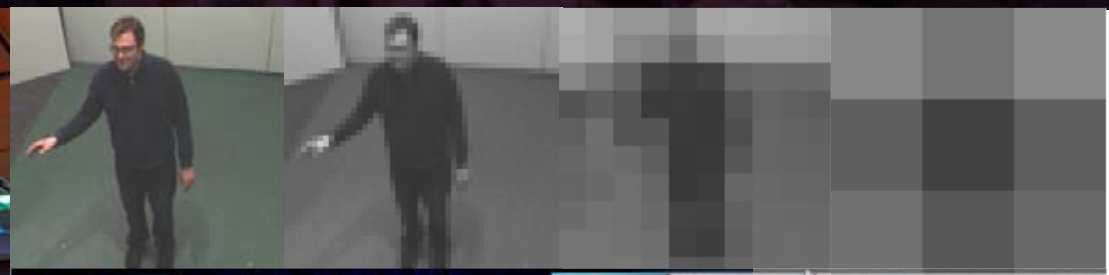
Industry Driving Forces	Factors	Average Relevance to Focal Issue (0-10 scale)	Comments	Rele
Factors within the lighting industry impacting the focal issue				
Trade Practice				
Design Trends				
Technology				
Economics				
Energy				
	Peak efficiency in lighting			
	Continuing drive to 200+ LPW			
Research				
	Challenges in research design methodologies			
Media Trends				
	Blue Light Risk			
	Circadian Everything- Health & Wellness etc.			
	"Smart" Lighting			
Regulatory				
	Qualified Product Lists- DLC, CEC, others			
	Proposed UL certification of Circadian lighting			

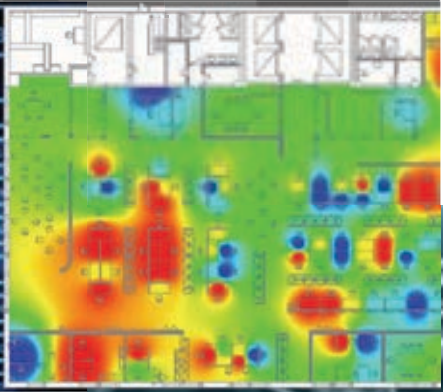


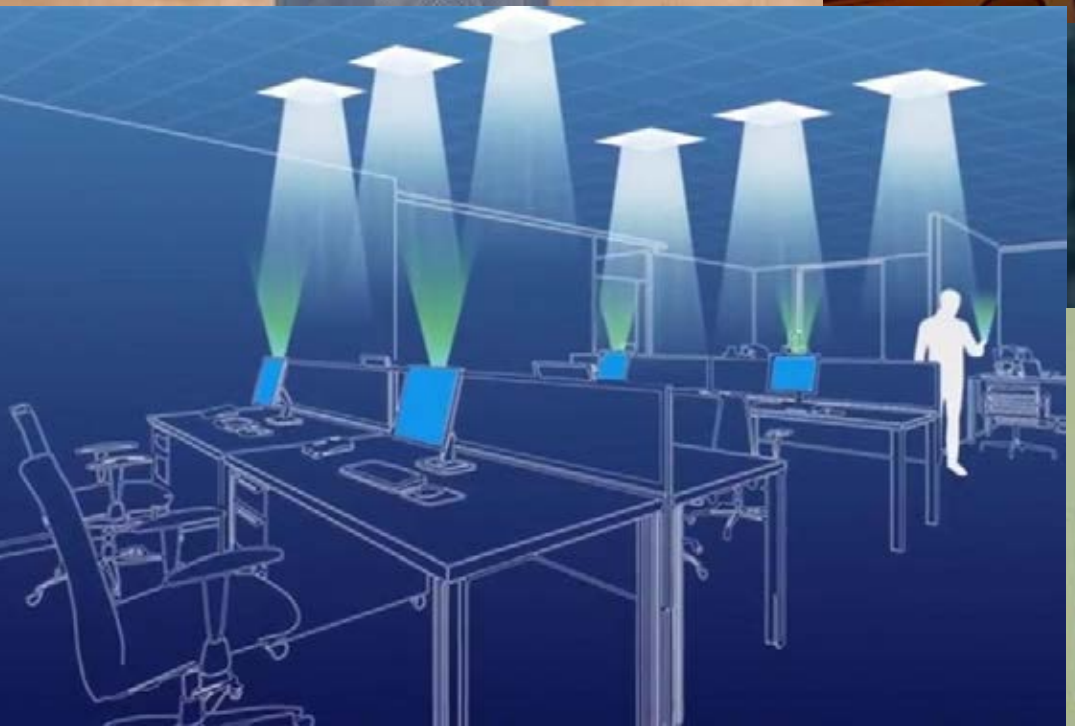
9. Four Shades of Future

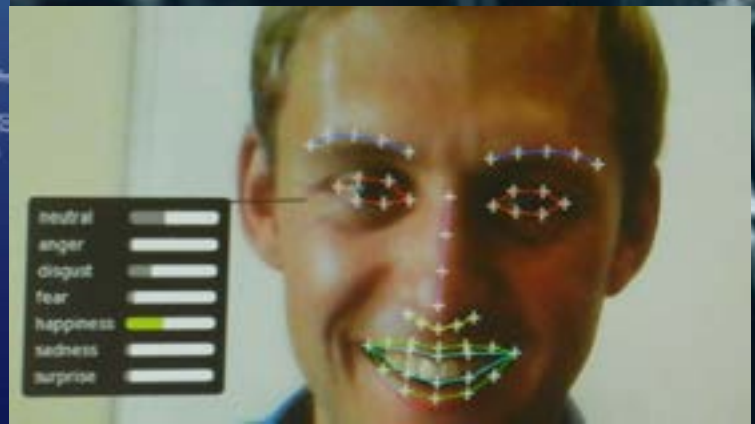


Scenario 1: Human-Free Systems









Scenario 1: Human-Free Systems

Narrative

Built environments adapt automatically to individual and group behavior and preferences, automatically sensing motion, interaction, and ambient conditions and adjusting services to optimize comfort, health, energy and operational efficiency.

Controls and systems have become too complex for most humans - every important function is now automated in order to remove human error

Deep sensor network collects data

Machine learning and AI optimize systems

Drivers

System Complexity
Cognitive Overload

Preventative Maintenance

Energy Efficiency

Asset Management

Indoor Environmental Quality

Portfolio Management

Health & Productivity

Safety and Emergency Response

Security

Data Monetization

Tech Stack

Biometrics – gait, emotion, thermal, identity

Ubiquitous sensors

Machine learning & AI

Integrated system controls

Light Field Sensing

LiFi, WiFi, VLC

Mobile Computing

GPS & IPS

Biomimetic Façade systems

Scenario 1: Human-Free Systems

Implications

Requires new ROI mindset

Requires new metrics for value of data

Requires new synthetic skillsets and job descriptions

Completely redefines maintenance roles

Requires a new concept of User Interface and entirely new designs and approaches

Requires advance new architectures for security of controls and data

Requires redefining emergency and backup power strategies

Early Signs

LiFi pilot projects- Paris Metro & others

Promising research prototypes in labs like LESA

Widespread deployment of sensor and data networks in lighting systems

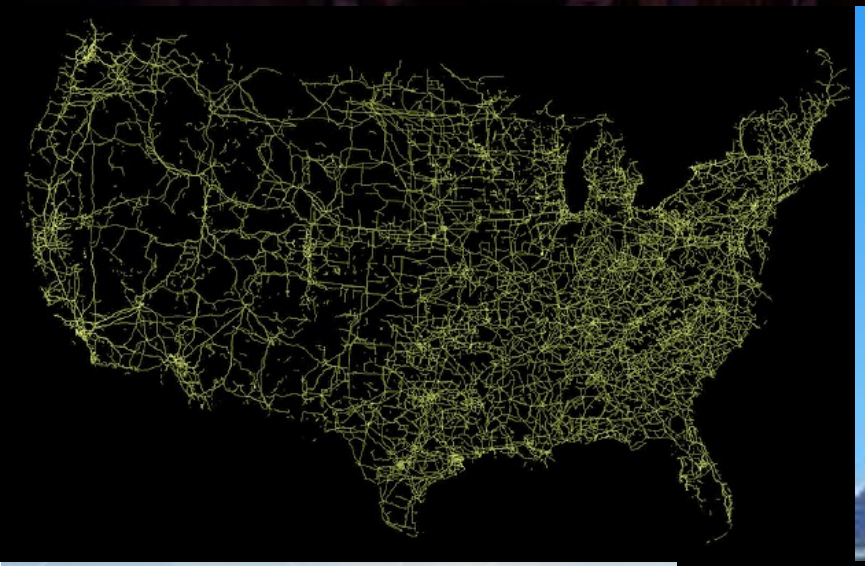
Widespread use of asset tracking and space utilization

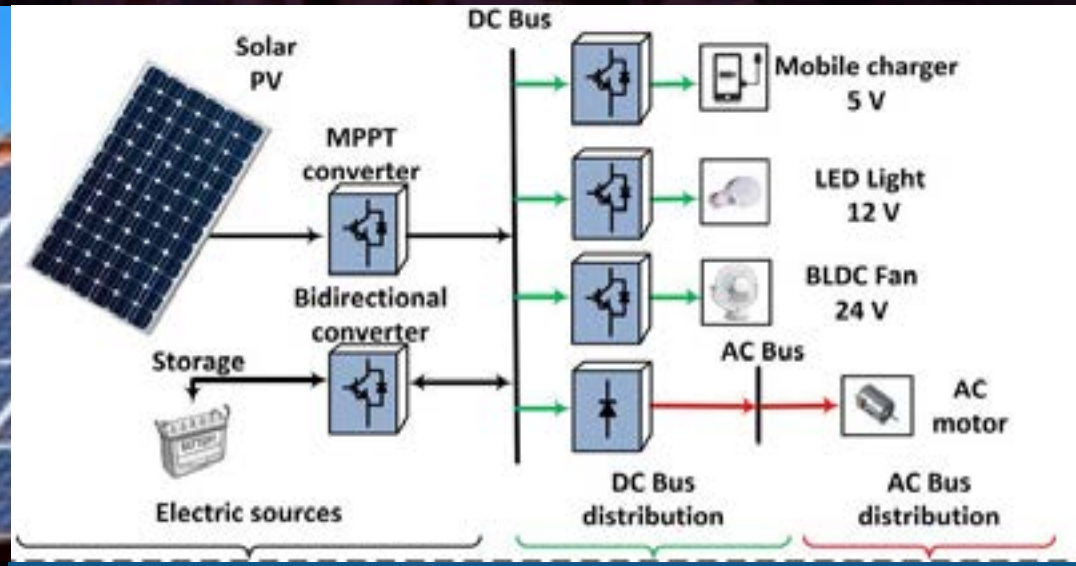
Pilot projects in integrated building controls

Advancements in emotion analytics, biometrics, and surveillance technology

Startups in wireless VLD space

Scenario 2: Convergent Grid





Scenario 2: Convergent Grid

Narrative

Low voltage DC systems at the grid edge emerge, enabled by the convergence of advanced storage, distributed generation, microgrids and nanogrids, and smart networks. Distribution networks evolve that transmit power and data over the same lines.

Low voltage DC lighting and other applications in homes drives the development of integrated energy and data systems and the conversion of large parts of the electrical grid to DC.

Drivers

Declining Cost of Solar

Energy Efficiency- eliminating conversion losses

Energy Security

Grid balancing

Resilience

Decentralization

Health & Productivity

Security

Safety

Material Efficiency

Simplified Compliance & Certifications

Tech Stack

DC battery storage

Solar and other renewables

LEDs

AI & Machine learning

Electric Vehicles

Smart Micro and Nanogrids

Wireless Mesh Networks

Data Analytics

Advanced integrated controls

New DC appliances

Digital Assistants

Blockchain

Scenario 2: Convergent Grid

Implications

All systems become safer, lighter, smaller, cheaper, more mobile, flexible, and efficient.

New platform for products and applications

Decentralized power impacts political, social, and economic organization

Declining cost of energy means higher equality of economic opportunity

Decarbonization is enhanced

Legacy grid evolves to handle renewable loads better

Role of Utilities is transformed dramatically

Installation, operation, and maintenance of LVDC systems is much easier and cheaper

LVDC systems help to balance the legacy grid

Early Signs

LVDC pilot programs in retail & residential

Many worldwide demonstation sites for DC systems

Dramatic increase in solar

Steady improvements in battery technology

Emerging LVDC power systems, including power servers, wiring, and other components

Widespread use of DC in data centers

Investment in and deployment of PoE

Widespread acceptance of EVs

Scenario 3: Illumigeddon

Illumigeddon

Narrative

Giant telecom, electronics, and communications corporations take over the specialized, fragmented lighting industry. Oil & gas companies take over utilities. Traditional market and distribution channels are disrupted.

Drivers

Consolidation, M&A

Disintermediation

Integration of Lighting with Electronics

Price drops in products

Inertia & lack of innovation in lighting

Declining R&D investment

Disruption mindset

Decline of Government leadership & regulation

Financialization

Tech Stack

Ubiquitous sensors

Smart everything

Big Data & Analytics

AI

Blockchain

Advanced UI & UX

Illumigeddon

Implications

Further siloization of architecture, engineering, construction and operation industries

Less need for specialized lighting consultants

Traditional distributors disappear

New need for technicians with cross-disciplinary skills

Declining consensus on standards

Rapid commoditization of components

Increasingly centralized power in the hands of private and semi-private corporations

Declining innovation

Early Signs

Sustained market churn – M&A musical chairs

Traditional players selling off lighting businesses

Entry of top tech firms into industry

Rise of IoT

Rapid commoditization of products

Declining innovation in lighting

Scenario 4: Bioenlightenment








Scenario 4: Bioenlightenment

Narrative

Buildings evolve that are designed to make maximum use of daylight and allow electric lighting to be dramatically more efficient, effective, and beautiful. Time honored principles of architecture and biomimetic design converge in a new vision of sustainable architecture. Learning from nature is enhanced with the realization that humans are part of nature too, and that many other species offer innovative and useful design solutions to architecture, specifically how it can deliver optimal light.

Drivers

Resilience

Climate adaptation

Biomimetic Design

Health & Productivity

Circular Economy

Security

Safety

Energy Efficiency

Lifecycle Impact Assessment

Daylight & Views

Tech Stack

Synbio

Advanced Materials

Generative/Parametric Design tools

Advanced storage + renewables + smart grid

LEDs

AI & Machine learning

Advanced sensors & Actuators

Data Analytics

Advanced integrated controls

Dynamic Daylight Controls

Scenario 4: Bioenlightenment

Implications

Lighting acquires a new significance as it reclaims it's position as a primary driver for architectural form.

Architecture, engineering, and construction disciplines become more integrated

A new focus on biological science informs design.

We develop a better understanding of interconnections between lighting and other building systems, including HVAC

Emerging technology in glazing materials also impact performance of photovoltaic systems

Early Signs

Emerging prototype biomimetic buildings

Advanced glazing and designs developed at Harvard Graduate School of Design

Biomimetic design research projects at major universities

Increasing interest in daylight and views

Increased interest in generative and resilient design

Developments in advanced glazing materials and systems

The Reality of Plural Modalities

Incandescent
Lamp & Luminaire

Declining
10 year Expiry

Incandescent
Luminaire
LED replacement
Lamp

Stable
30 year Expiry

“Modular”
LED Luminaire

Interim
5 year Expiry

“Integrated”
LED Luminaire

Growing
15 year Expiry

LED Driven
Form

Emerging
Expiry ?

Summary

Longer lifetimes are not necessarily better

Nothing is Inevitable

History is cyclical, not linear

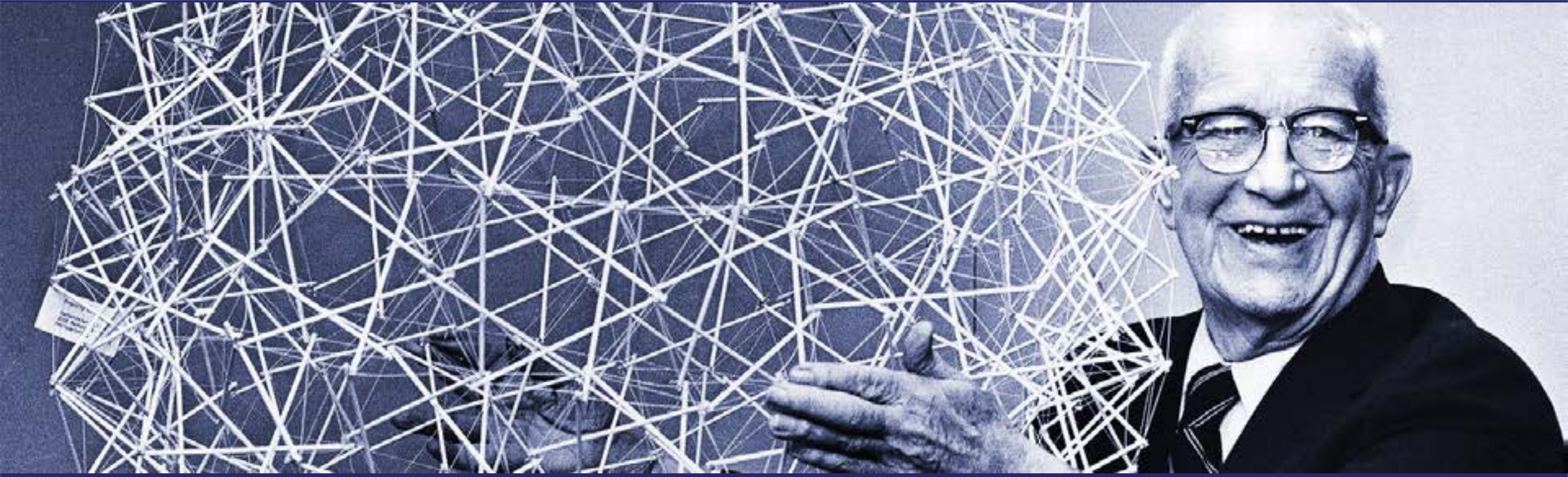
Copy Nature

Disruptive change cannot be permanent by definition

Design and Implementation are more powerful than Innovation

We can make better forecasts with smart crowdsourcing

The Future will be Plural & Multivariate, as always!



We are called to be the architects of the future, not its victims.

- Buckminster Fuller

Special Thanks to:

Jim Benya

Alex Baker

Thomas Paterson

Eric Bretschneider

Susan Larson

Mark Lien

Robert Karlicek

This Concludes The American Institute of Architects
Continuing Education Systems Course

Clifton Lemon Associates

Clifton Stanley Lemon

cl@cliftonlemon.com

415 254 7056