AABC Commissioning Group

AIA Provider Number 50111116

99.999% Uptime: Beyond the Numbers in Datacenter Reliability

Course Number: CXENERGY1632

Tor Kyaagba, PE, CEM

Google

April 12, 2016

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

Course Description

Datacenters are at the apex of mission criticality. "99.99% uptime" is more than a hope or target, it's a management system.

Attendees will learn how to balance the benefits and costs associated with trying to achieve greater energy efficiency, reliability, and lower operating costs as well as the requirements of the applicable codes and standards, including The Green Grid: PUE (power usage effectiveness) Metric.

Learning Objectives

At the end of the this course, participants will be able to:

1. Differentiate between the terms reliability, availability, up-time, and redundancy, specifically in the context of mission-critical datacenters.

2. Understand how The Green Grid PUE is calculated, as well as it's usefulness and limitations as an energy efficiency metric in datacenter design and operation.

3. Understand how availability and PUE affect CAPEX, OPEX and revenues in different datacenter types, and how these drive design and operational decisions.

4. List some factors that often undermine a critical facility's reliability or PUE, and identify strategies to eliminate or minimize them.

Mission Critical Systems (Healthcare)

POWER OUTAGE
=
LONGER TIME FOR LAB TESTS
+
LOST ORGANIC SAMPLES

POWER OUTAGE
=
LOSS OF LIFE SUPPORT
+
DELAY TO SURGICAL OPERATIONS
(LIFE & DEATH SITUATIONS)

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Mission Critical Systems (Banking & Retail)

ATM OUT OF SERVICE
=
LOST REVENUE (NO SERVICE CHARGES)
+
DISSATISFIED CUSTOMER

E-COMMERCE SITE DOWN
=
LOST REVENUE (NO SALES)
+
DISSATISFIED CUSTOMER

Mission Critical Systems (Financial Securities)

Image courtesy of worradmu at FreeDigitalPhotos.net

ELECTRONIC SYSTEMS DOWN
=
LOST REVENUE (NO TRADE COMMISSIONS)
+
DISSATISFIED CUSTOMER
+
RIPPLE EFFECT IN FINANCIAL MARKETS

Mission Critical Systems (Aviation)

Image courtesy of trankny242 at FreeDigitalPhotos.net

Image courtesy of tratong at FreeDigitalPhotos.net

AIRPORT CRITICAL SYSTEMS

CONTROL TOWER
RUNWAY LIGHTING
AIRPORT LIFE SAFETY SYSTEMS
AIRPORT SECURITY SYSTEMS

AIRLINE COMPUTER SYSTEMS TIED TO

TICKETING KIOSKS
AUTOMATIC LUGGAGE DROP OFF
FLIGHT SCHEDULING
ONLINE RESERVATION SYSTEMS
AND MORE…

Mission Critical Systems (Data Centers)

Image courtesy of Sujin Jetkasettakorn at FreeDigitalPhotos.net

Image courtesy of antpkr at FreeDigitalPhotos.net

SOFTWARE
+
COMPUTE + NETWORK + STORAGE
+
SITE INFRASTRUCTURE

MUST ↓ **BE**

HIGHLY RELIABILE
+
HIGHLY AVAILABLE

FOLLOW THE $$$$

$5.6 BILLION
$868 MILLION
$1.3 BILLION
$2.7 BILLION

1
8.5%
$32 BILLION

FOLLOW THE $$$$

$5.6 BILLION (DC ASSETS)
$868 MILLION (DC CAPEX)
$1.3 BILLION (DC OPEX)
$2.7 BILLION (REVENUE)

8.5% (MARKET SHARE)
$32 BILLION (MARKET SIZE)

NASDAQ: XXXX 10K 2015 BALANCE SHEET

$5.6 BILLION (DATA CENTER ASSETS)*

Consolidated Balance Sheets
(in thousands, except share and per share data)

	December 31, 2015		December 31, 2014	
Assets				
Current assets:				
Cash and cash equivalents	$	2,228,838	$	610,917
Short-term investments		12,875		529,395
Accounts receivable, net of allowance for doubtful accounts of $10,352 and $9,466		291,964		262,570
Current portion of restricted cash		479,417		3,057
Other current assets		212,929		85,004
Assets held for sale		33,257		—
Total current assets		3,259,280		1,490,943
Long-term investments		4,584		439
Property, plant and equipment, net		5,606,436		4,998,270
Goodwill		1,063,200		1,002,129
Intangible assets, net		224,565		147,527
Restricted cash, less current portion		10,172		14,060
Other assets		188,458		128,610
Total assets	$	10,356,695	$	7,781,978
Liabilities and Stockholders' Equity				

NASDAQ: XXXX 10K 2015 CASHFLOW STATEMENT

$868 MILLION (CAPEX DATA CENTER SPEND)

Consolidated Statements of Cash Flows
(in thousands)

	Years ended December 31,		
	2015	2014	2013
Cash flows from operating activities:			
Net income (loss)	$ 187,774	$ (260,726)	$ 96,123
Adjustments to reconcile net income (loss) to net cash provided by operating activities:			
Depreciation	498,134	453,935	405,444
Stock-based compensation	132,443	117,990	102,940
Excess tax benefits from stock-based compensation	(30)	(19,582)	(27,330)
Amortization of intangible assets	27,446	27,756	27,027
Amortization of debt issuance costs and debt discounts	16,050	18,667	23,868
Provision for allowance for doubtful accounts	5,037	7,093	5,819
Restructuring charges (reversals)	—	—	(4,837)
Loss on debt extinguishment	289	156,990	108,501
Foreign currency transactions and other, net	16,490	19,912	11,543
Changes in operating assets and liabilities:			
Accounts receivable	(44,583)	(101,966)	(27,956)
Income taxes, net	(109,579)	226,774	(108,189)
Other assets	(70,371)	(6,496)	(36,853)
Accounts payable and accrued expenses	109,125	10,681	7,242
Other liabilities	126,568	38,392	21,266
Net cash provided by operating activities	894,793	689,420	604,608
Cash flows from investing activities:			
Purchases of investments	(359,031)	(545,997)	(968,971)
Sales of investments	837,708	573,582	276,351
Maturities of investments	35,431	211,966	213,484
Business acquisitions, net of cash acquired	(245,553)	—	(49,337)
Purchases of real estate	(38,282)	(16,791)	(74,332)
Purchases of other property, plant and equipment	(868,120)	(660,203)	(572,406)
Increase in restricted cash	(512,319)	(968)	(837,190)
Release of restricted cash	15,239	2,572	843,088

NASDAQ: XXXX 10K 2015 INCOME STATEMENT

$1.3 BILLION (OPEX - ENERGY EFFICIENCY)

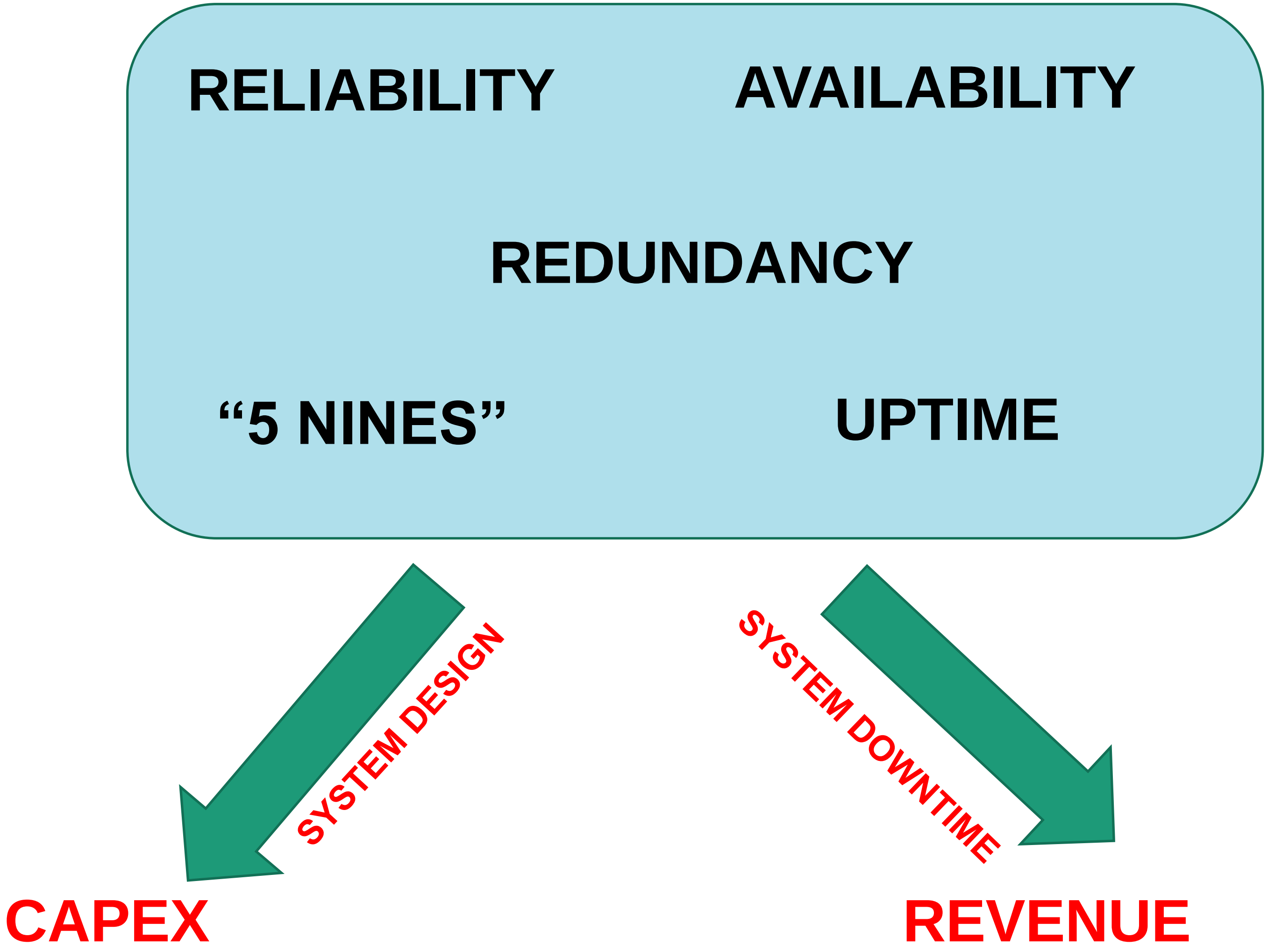
$2.7 BILLION (REVENUE - UPTIME)

Consolidated Statements of Operations
(in thousands, except per share data)

	Years ended December 31, 2015	2014	2013
Revenues	$ 2,725,867	$ 2,443,776	$ 2,152,766
Costs and operating expenses:			
Cost of revenues	1,291,506	1,197,885	1,064,403
Sales and marketing	332,012	296,103	246,623
General and administrative	493,284	438,016	374,790
Restructuring reversals	—	—	(4,837)
Acquisition costs	41,723	2,506	10,855
Total costs and operating expenses	2,158,525	1,934,510	1,691,834
Income from operations	567,342	509,266	460,932
Interest income	3,581	2,891	3,387
Interest expense	(299,055)	(270,553)	(248,792)
Other income (expense)	(60,581)	119	5,253
Loss on debt extinguishment	(289)	(156,990)	(108,501)
Income from operations before income taxes	210,998	84,733	112,279
Income tax expense	(23,224)	(345,459)	(16,156)
Net income (loss)	187,774	(260,726)	96,123
Net (income) loss attributable to redeemable non-controlling interests	—	1,179	(1,438)
Net income (loss) attributable to Equinix	$ 187,774	$ (259,547)	$ 94,685
Earnings per share ("EPS") attributable to Equinix:			
Basic EPS	$ 3.25	$ (4.96)	$ 1.92
Weighted-average shares	57,790	52,359	49,438
Diluted EPS	$ 3.21	$ (4.96)	$ 1.89
Weighted-average shares	58,483	52,359	50,116

See accompanying notes to consolidated financial statements.

CapEx


RELIABILITY
AVAILABILITY
REDUNDANCY
“5 NINES”
UPTIME
SYSTEM DESIGN
SYSTEM DOWNTIME
CAPEX
REVENUE

Reliability

PROBABILITY

SUCCESS

TIME

RELIABILITY of a system (applied within limits of it's design) is the **PROBABILITY** that it will operate or function **SUCCESSFULLY** for a specified **TIME** duration

RELIABILITY of a system (applied within limits of it's design) is the **PROBABILITY** that it will **NOT FAIL** within a specified **TIME** duration.

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Availability

RATIO

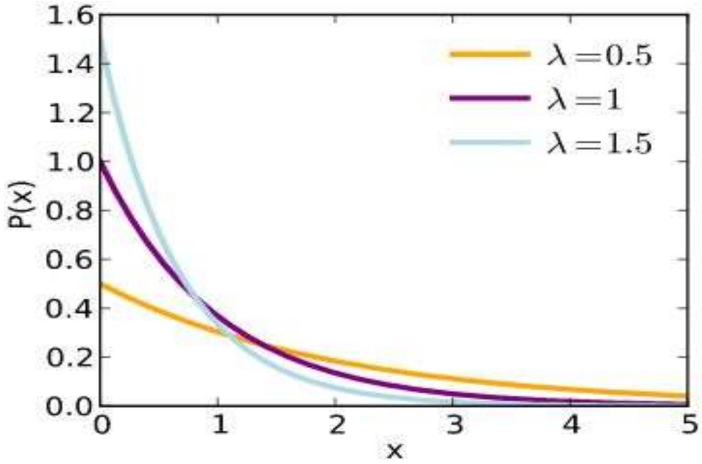
UPTIME

TOTAL TIME

AVAILABILITY of a system (applied within limits of it's design) is the **RATIO** of Uptime to the total **TIME** duration being analyzed.

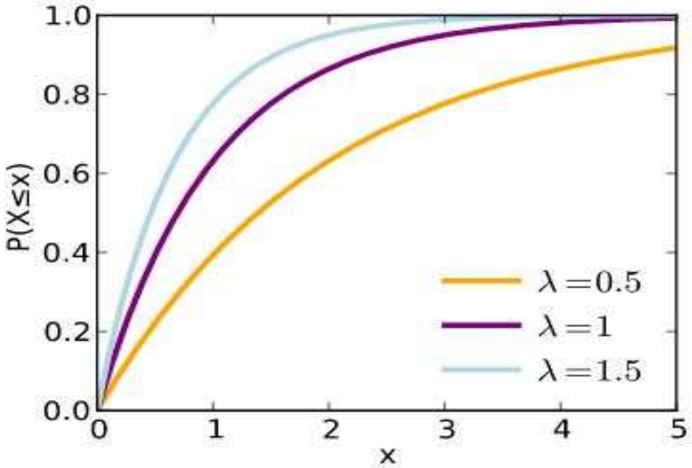
Usually expressed as a percentage

Reliability (PDF, CDF)



$$f(x) = \lambda e^{-\lambda x}$$

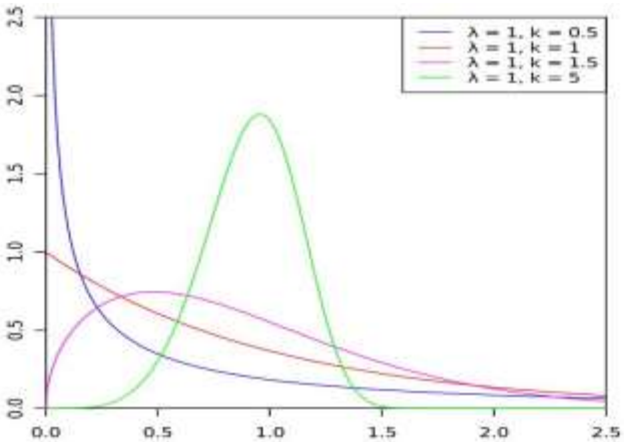
Probability Density Function
(Exponential Distribution)



$$R(x) = e^{-\lambda x}$$

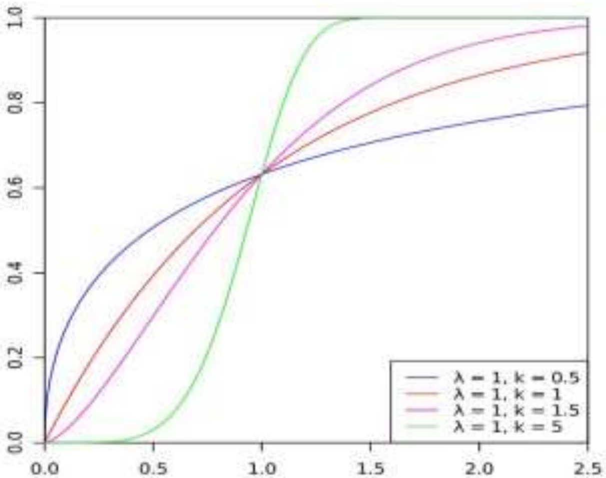
Cumulative Density Function
(Exponential Distribution)

Reliability (PDF, CDF)



$$f(x; \lambda, k) = \frac{k}{\lambda}(x/\lambda)^{k-1} e^{-(x/\lambda)^k}$$

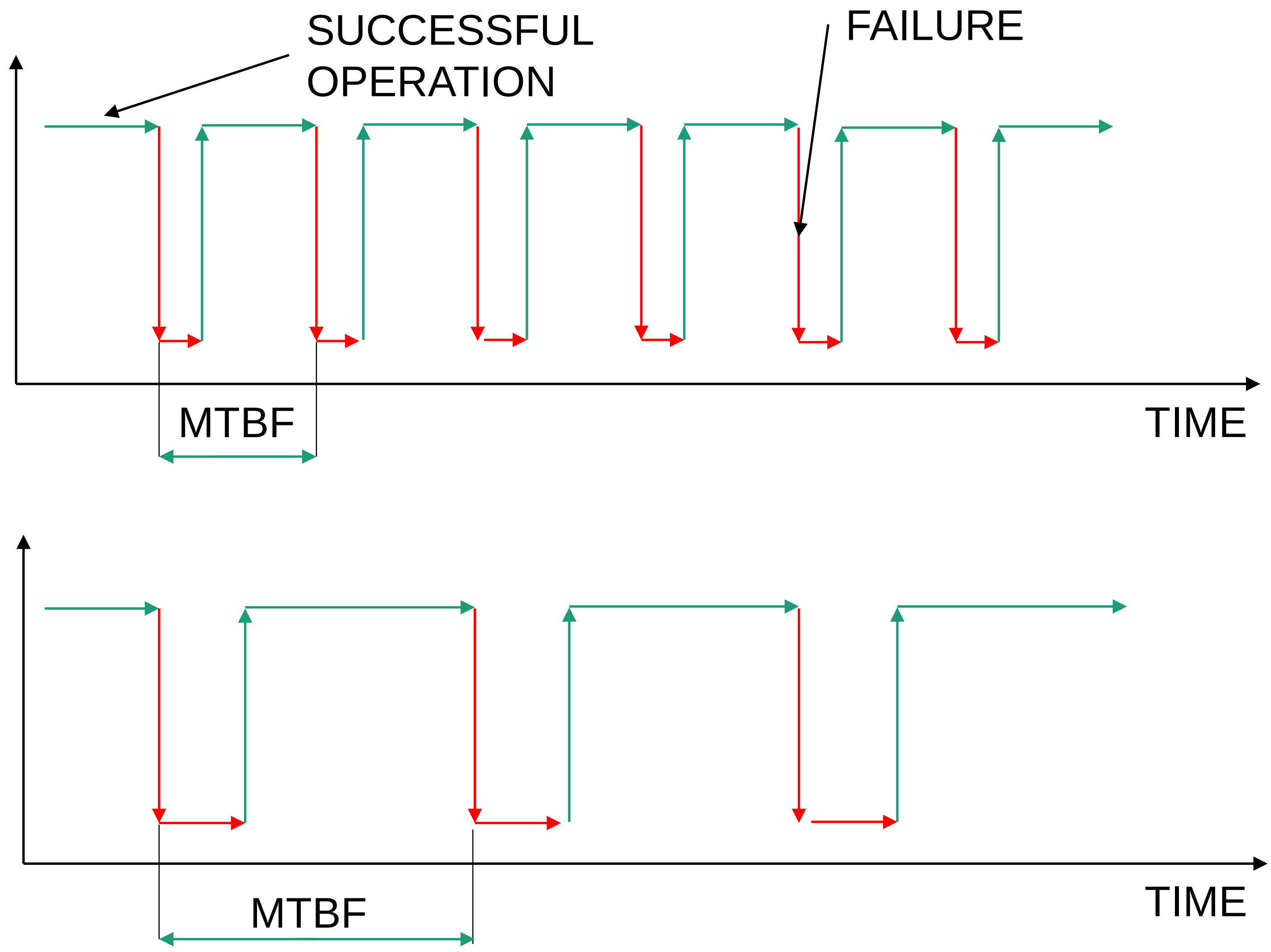
Probability Density Function
(Weibull Distribution 2 parameter)



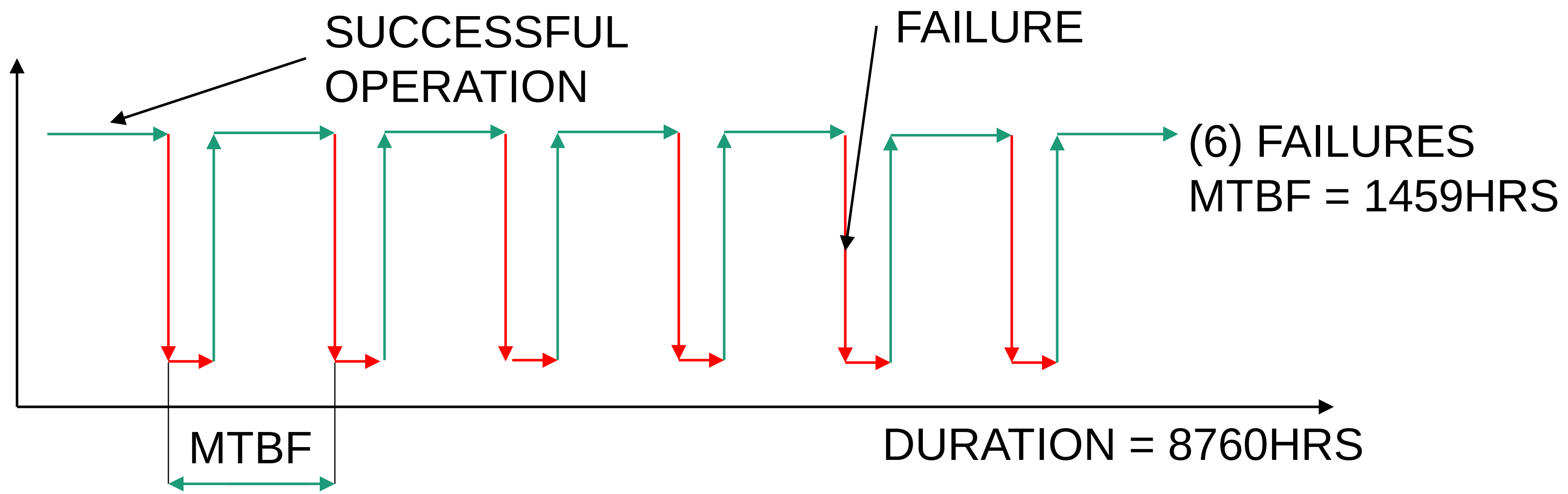
$$R(x) = e^{-(x/\lambda)^k}$$

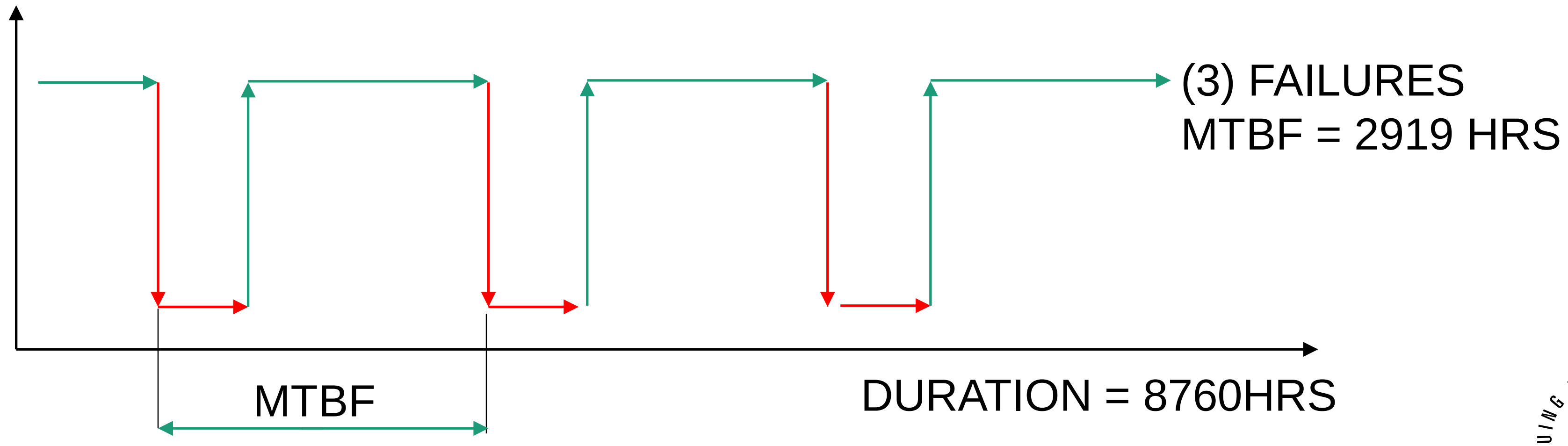
Cumulative Density Function
(Weibull Distribution 2 parameter)

Reliability (MTBF)

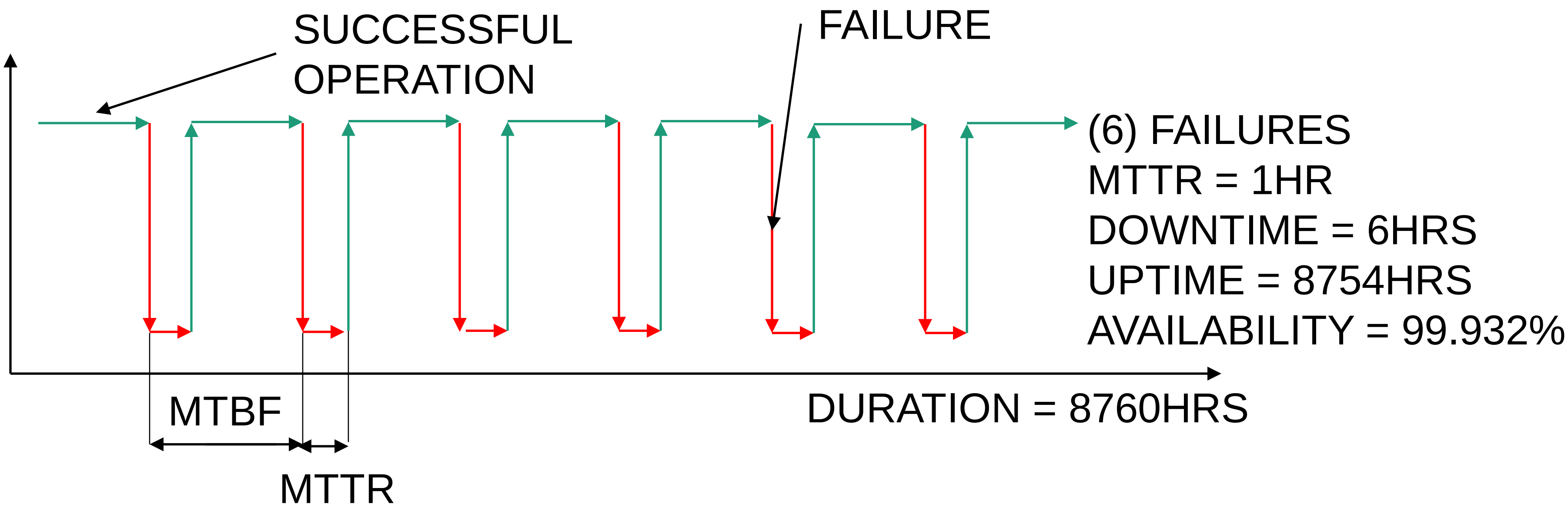


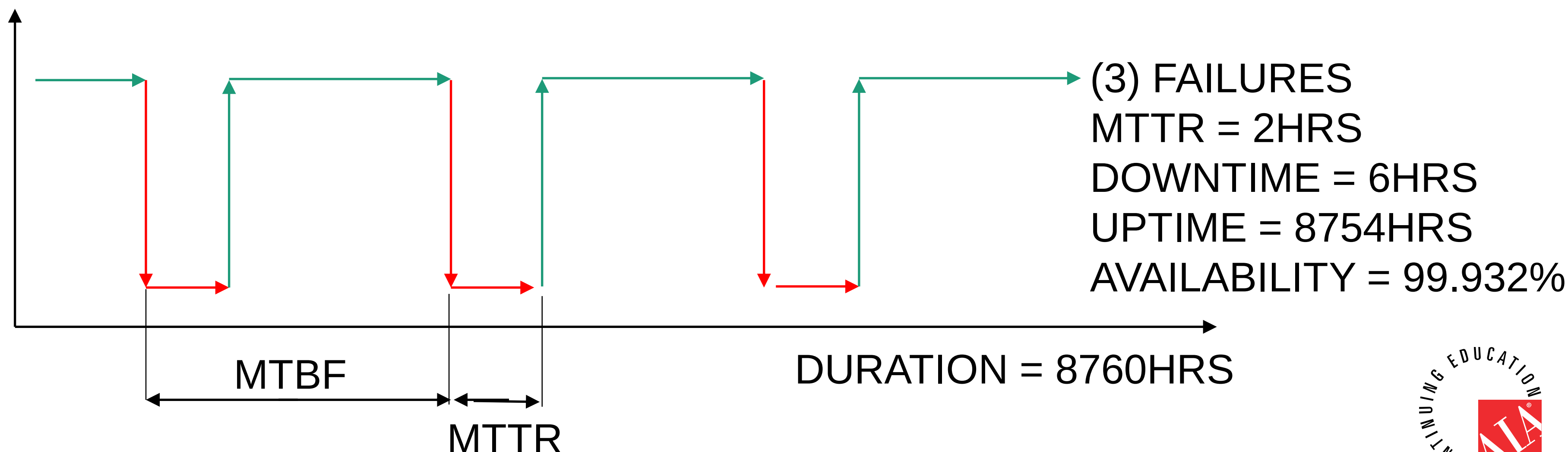
Reliability (MTBF)





Availability





Reliability / Availability

1. INCREASE RELIABILITY (INCREASE MTBF)
2. INCREASE AVAILABILITY (REDUCE MTTR)
3. MINIMIZE SYSTEM COST

Redundancy

N + R

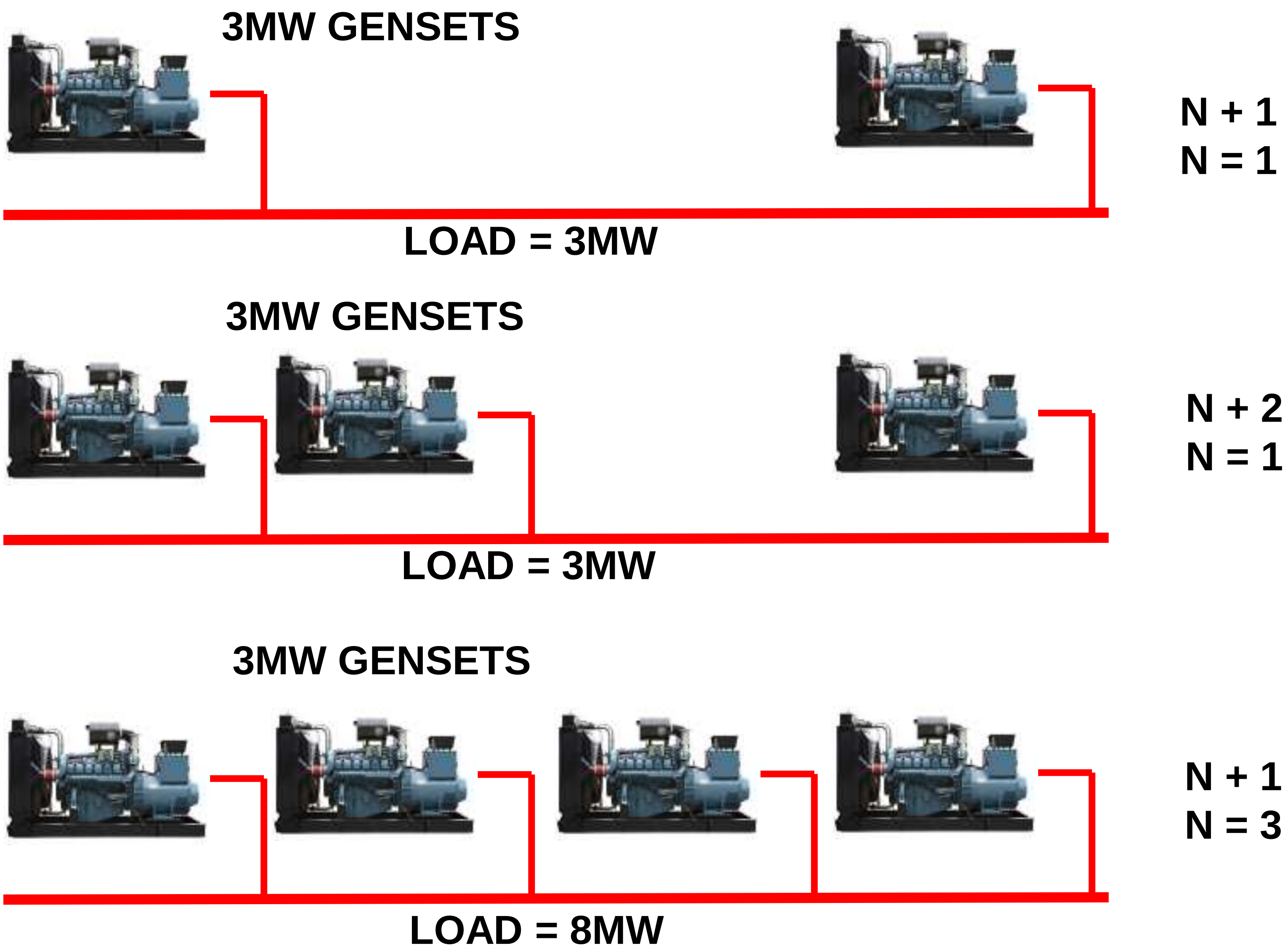
OR

X(N+R)

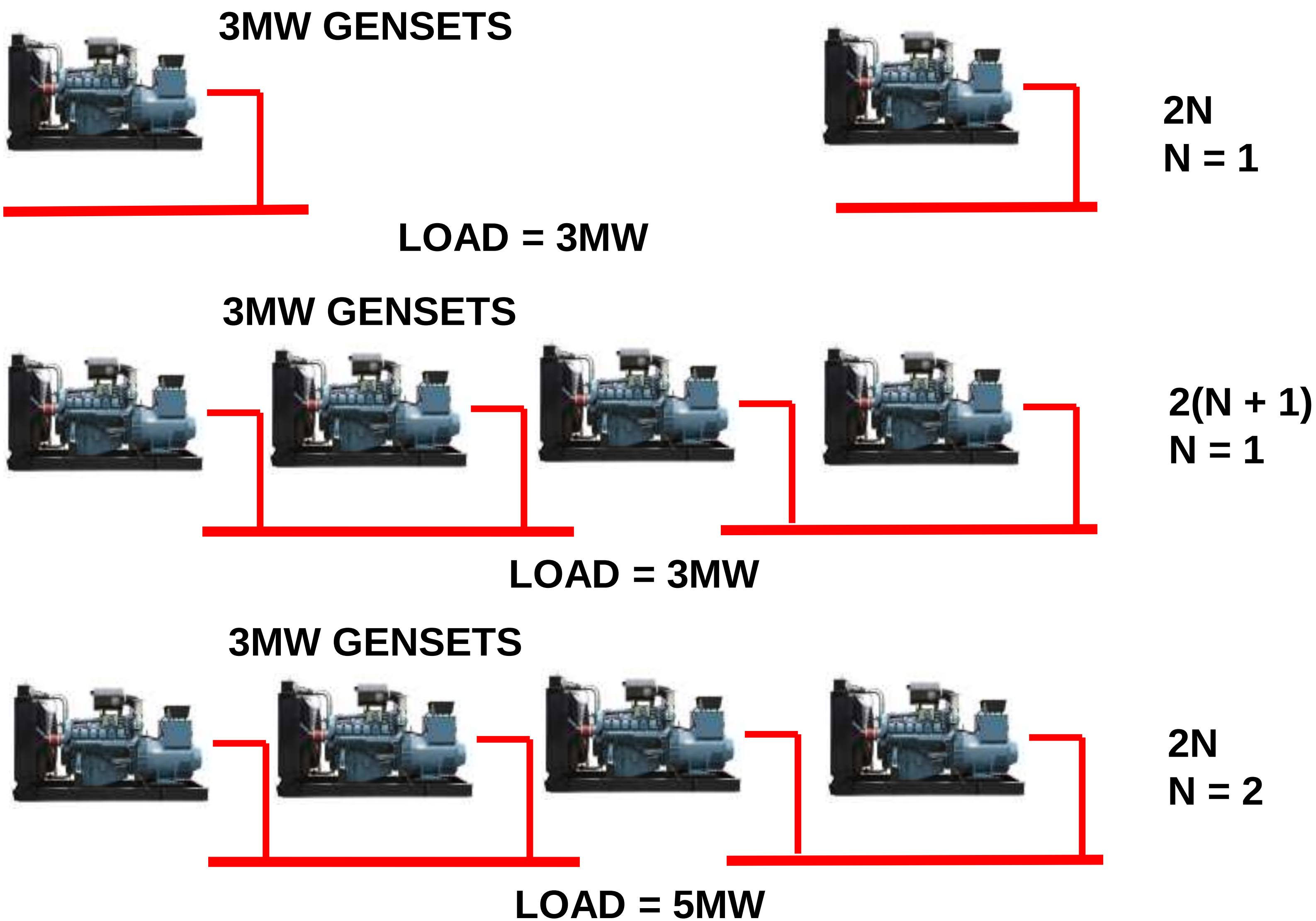
REDUNDANCY is ONE of the strategies for increasing system reliability by including functionally identical components above and beyond the number required for capacity such that failure of a single component does not result in system failure.

Usually expressed as an Equation

Redundancy (N+R)



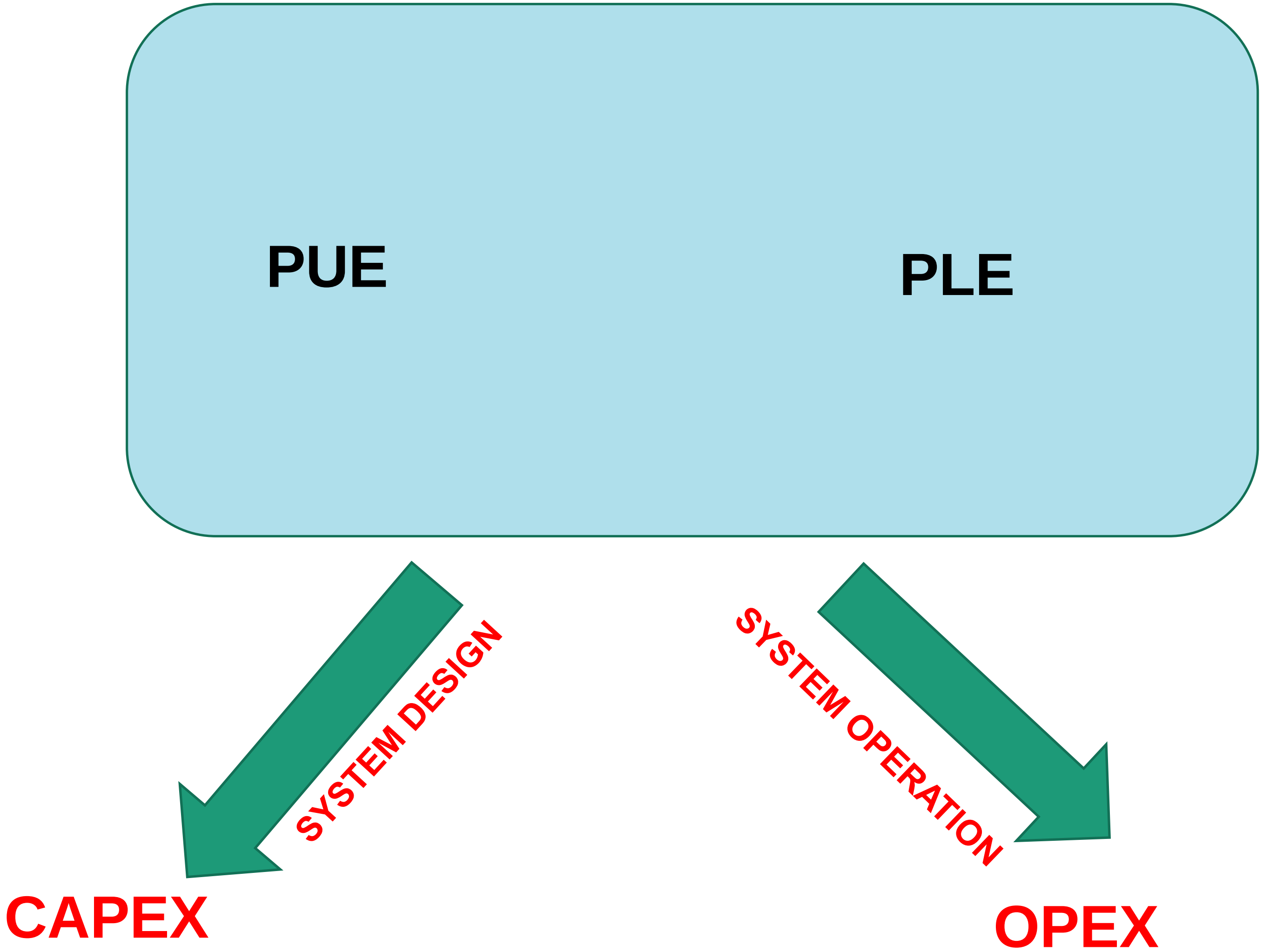
Redundancy X(N+R)



Reliability Engineering = Risk Management

1. IDENTIFY FAILURE MODE(S)
2. QUANTIFY THE SEVERITY OF FAILURE
3. ASSESS THE LIKELIHOOD OF FAILURE
4. EVALUATE COST/BENEFIT OF RISK MITIGATION OPTIONS.

CapEx



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NASDAQ: XXXX 10K 2015 BALANCE SHEET

COST OF REV., $1.3B
~ 25% OF ASSET VALUE

$5.0 BILLION
(2014 DATA
CENTER ASSETS)*

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Other assets	188,458	128,610
Total assets	$ 10,356,695	$ 7,781,978
Liabilities and Stockholders' Equity		

PUE

$$PUE = \frac{P_{Total}}{P_{I.T.}}$$

$$PUE = \frac{P_{I.T.} + P_{mech} + P_{elec} + P_{facility}}{P_{I.T.}}$$

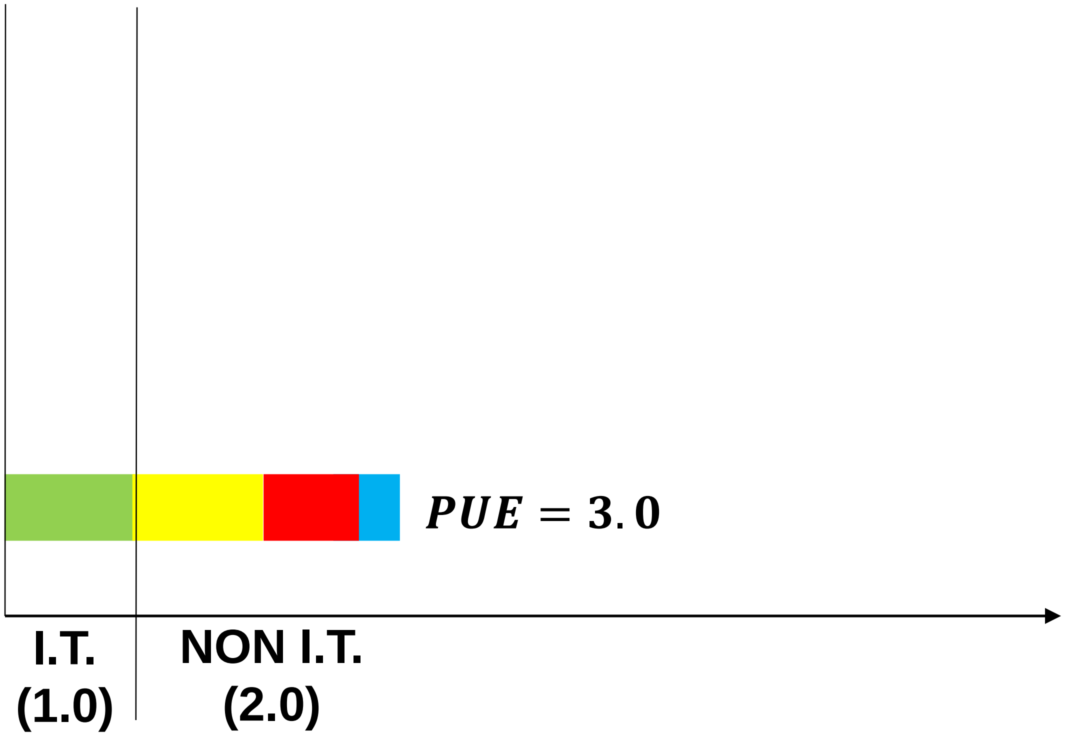
$$PUE = 1 + \frac{P_{mech}}{P_{I.T.}} + \frac{P_{elec}}{P_{I.T.}} + \frac{P_{facility}}{P_{I.T.}}$$

POWER USAGE EFFECTIVENESS in a datacenter is the ratio of TOTAL data center power consumption to the I.T. power consumption.

It is a measure of the "Overhead" power consumption in a datacenter, not used by I.T. equipment.

PUE

$$PUE = 1 + \frac{P_{mech}}{P_{I.T.}} + \frac{P_{elec}}{P_{I.T.}} + \frac{P_{facility}}{P_{I.T.}}$$



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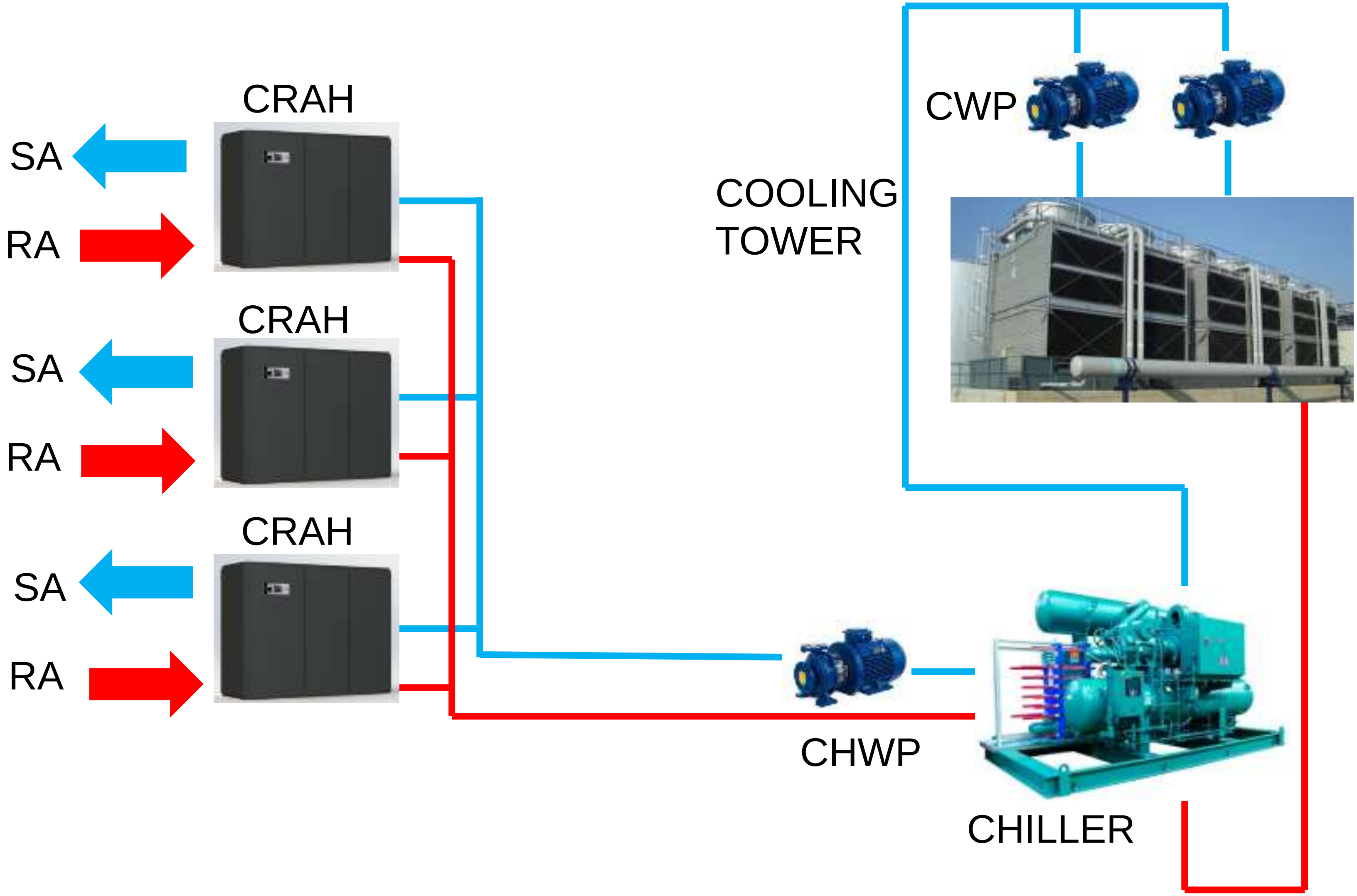
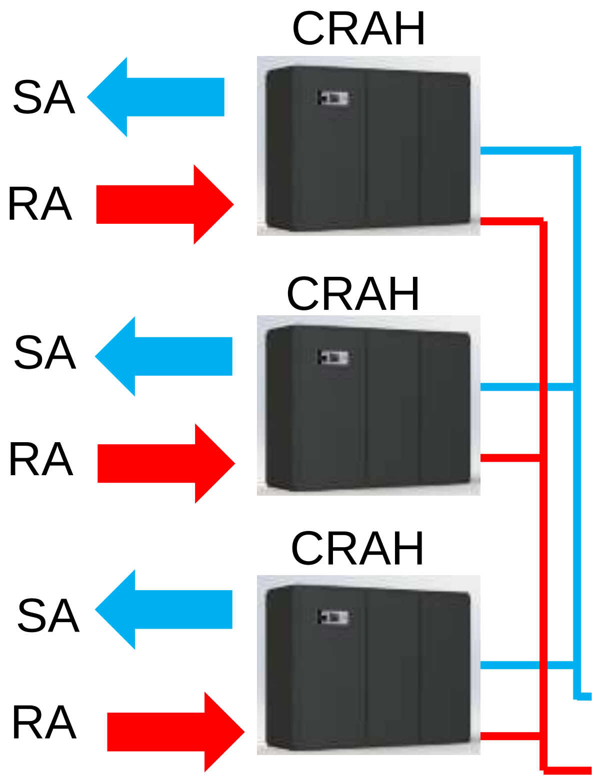
PUE – Mechanical Component



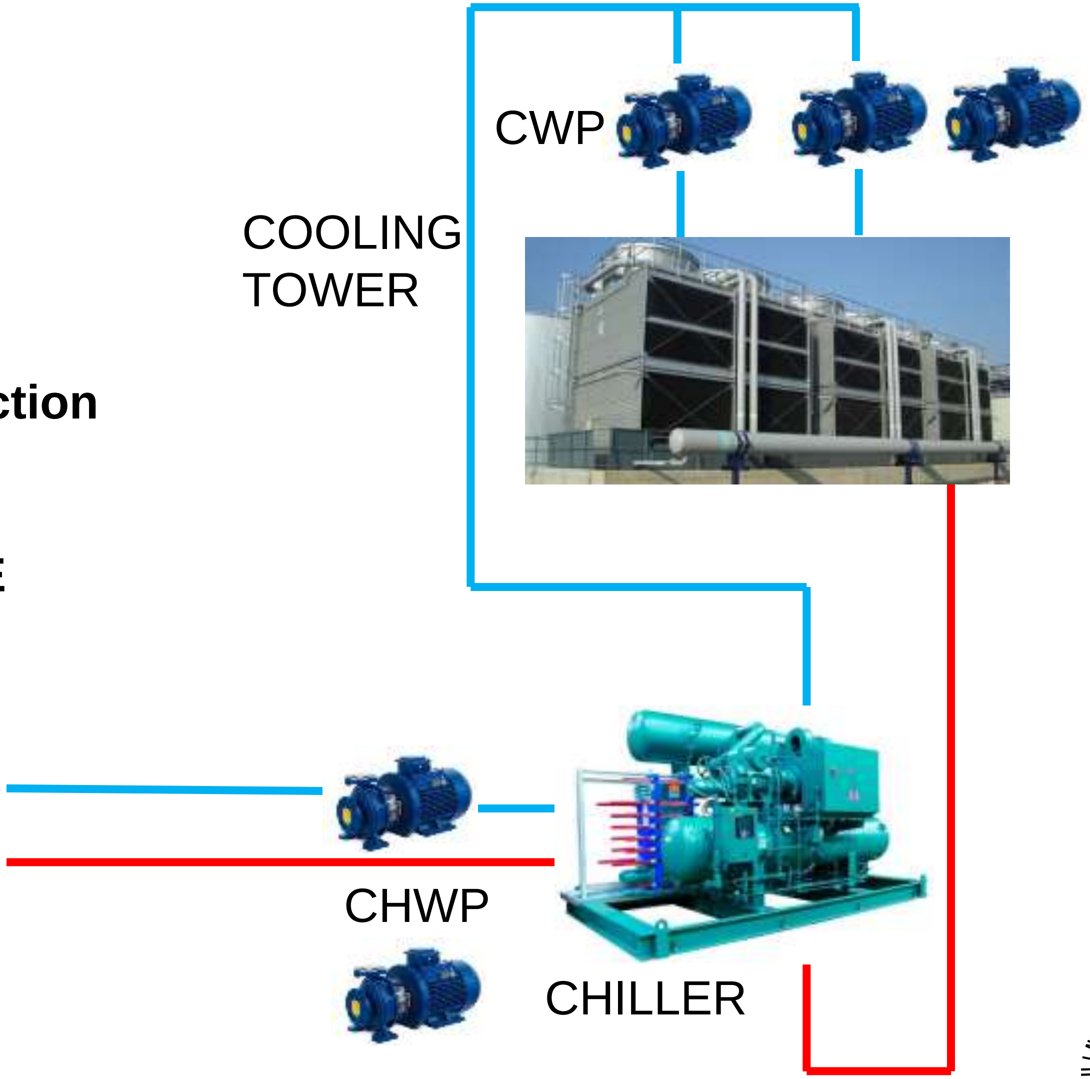
PUE Reduction – Mechanical Component



- **AISLE CONTAINMENT**
- **CFD ANALYSIS**
- **ECM FANS**
- **HIGHER EFFICIENCY COILS**

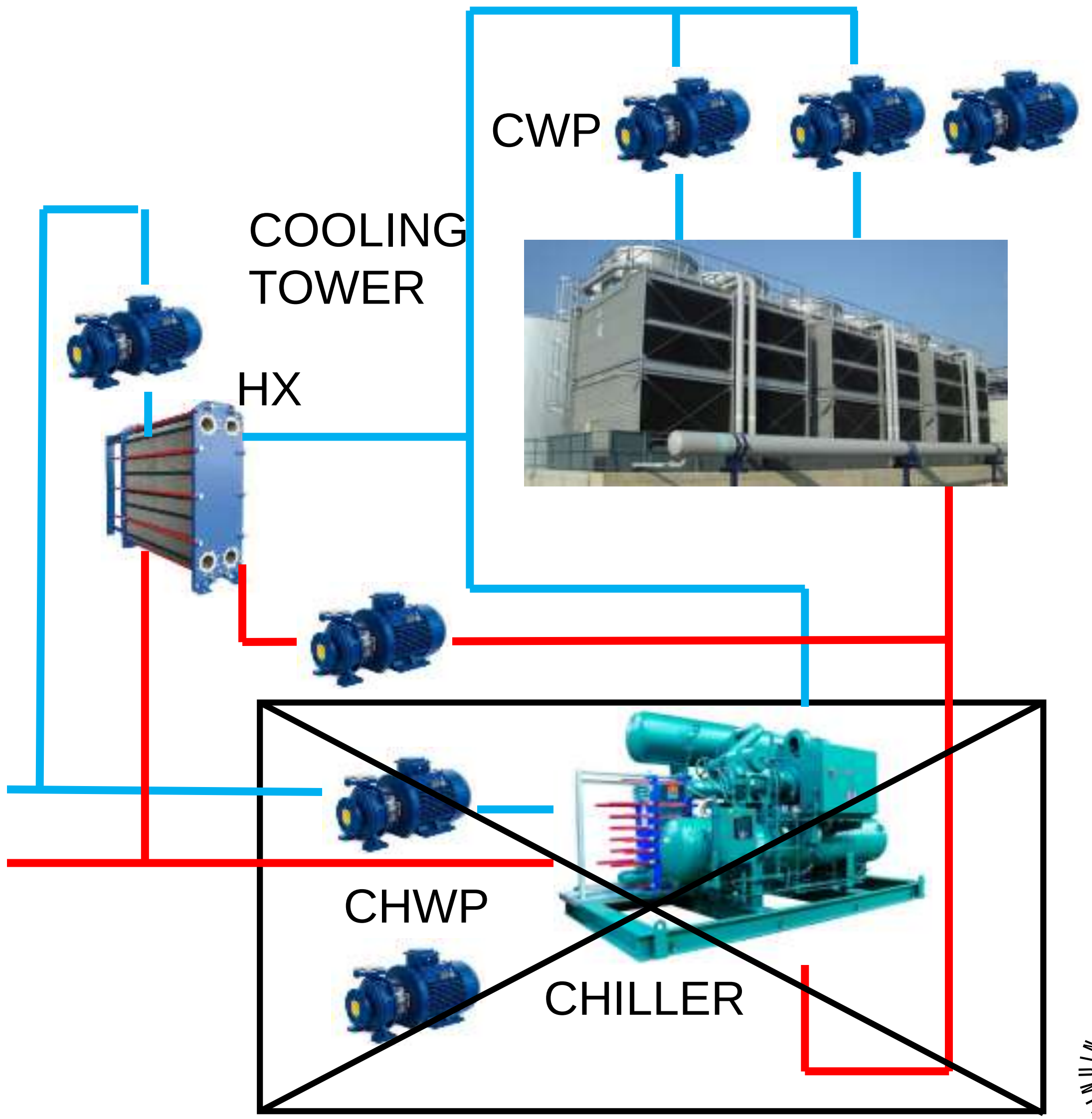
PUE Reduction – Mechanical Component

- **VFDs**
- **AFFINITY LAWS**
  $P \propto \omega^3$
  20% reduction in flow equates to ~50% reduction in power use.
- **EFFICIENT PIPE ROUTE DESIGN**



PUE Reduction – Mechanical Component

- **Economizer Mode**

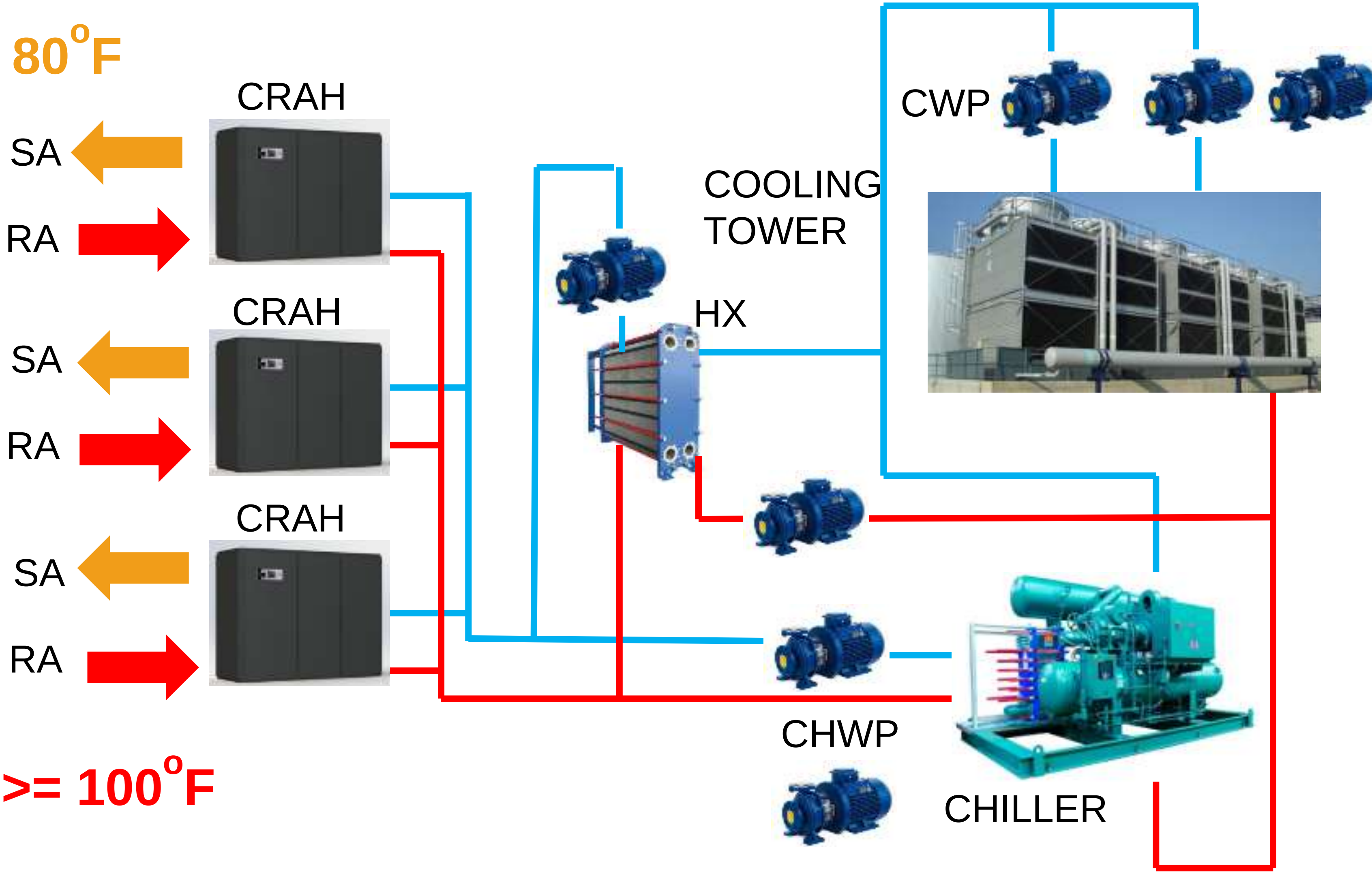


PUE Reduction – Mechanical Component

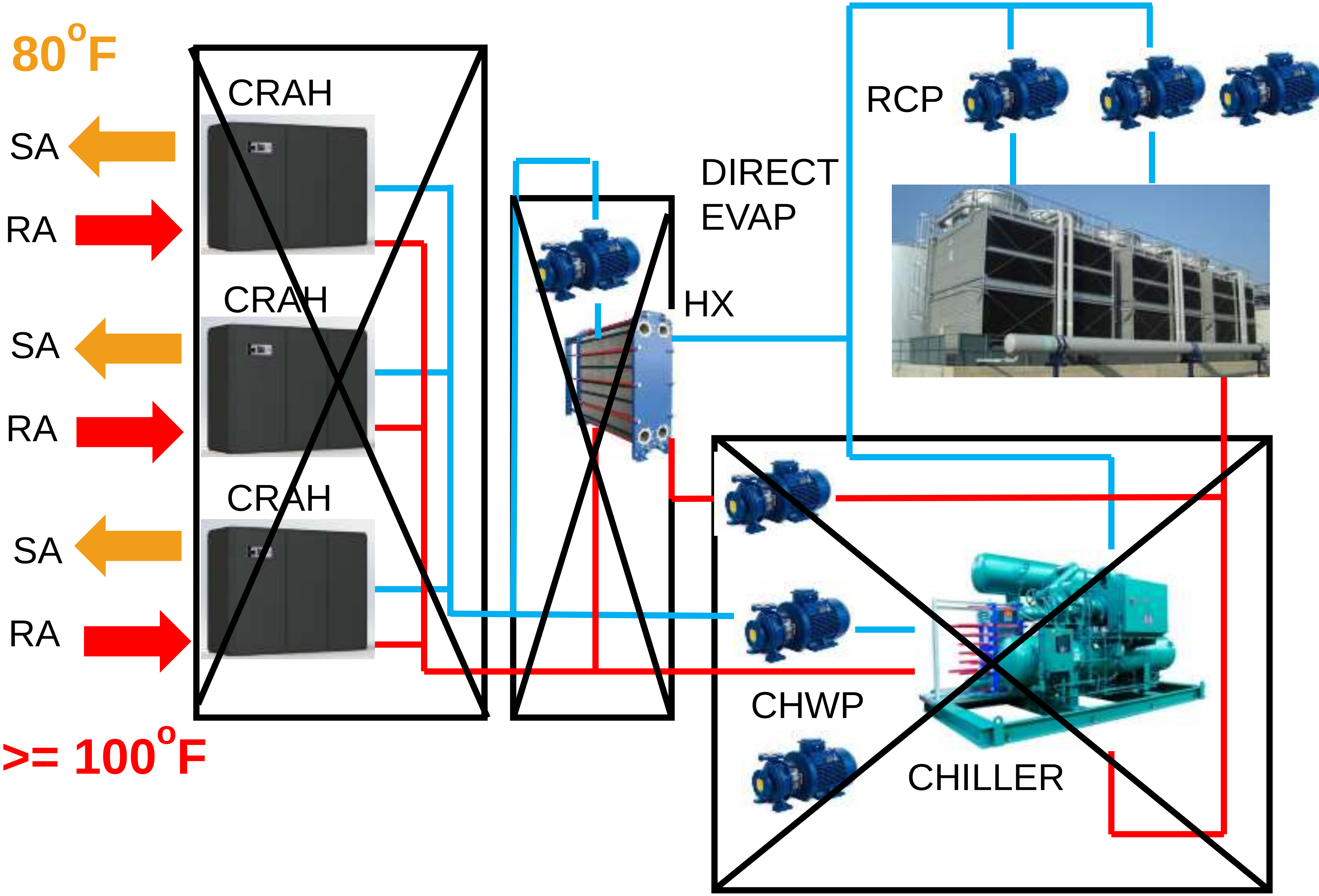
ASHRAE TC 9.9
Thermal Guidelines for Data Processing Environments

	2004 Version	2008 Version
Low End Temperature	20° C (68 ° F)	18° C (64.4 ° F)
High End Temperature	25° C (77 ° F)	27° C (80.6 ° F)
Low End Moisture	40% RH	5.5° C DP (41.9 ° F)
High End Moisture	55% RH	60% RH & 15° C DP (59 ° F DP)

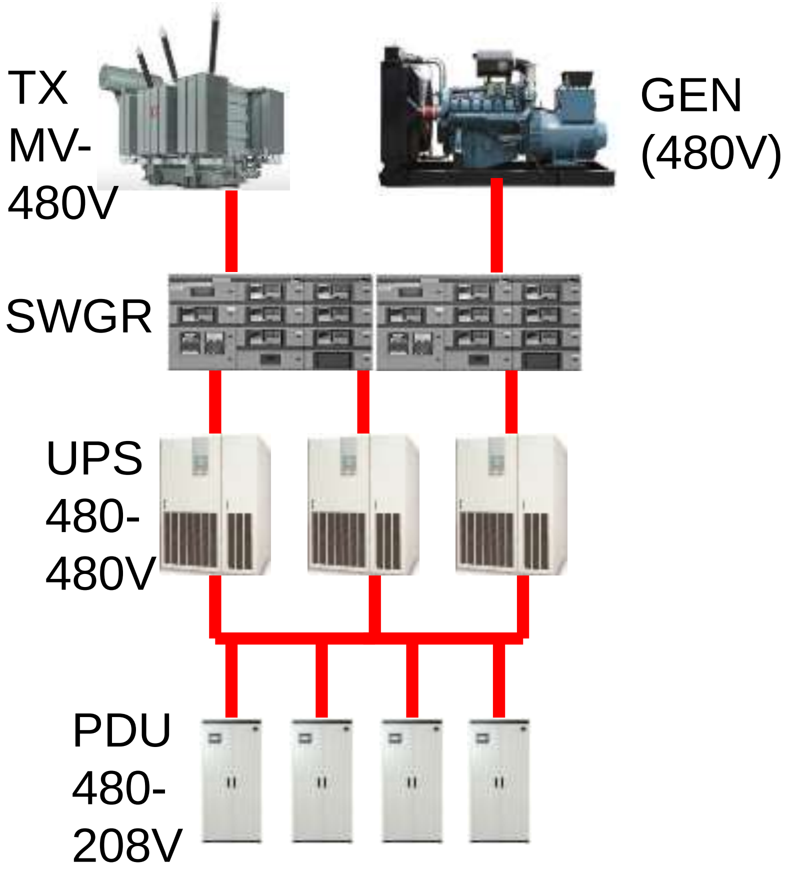
PUE Reduction – Mechanical Component



PUE Reduction – Mechanical Component



PUE Reduction – Electrical Component



ELECTRICAL LOSSES

- **TRANSFORMATION LOSS (POWER TX)**
- **FEEDER LOSSES – I2R**
- **POWER CONVERSION LOSSES (UPS)**
- **PART LOAD EFFICIENCY**

PUE Reduction – Facility Component

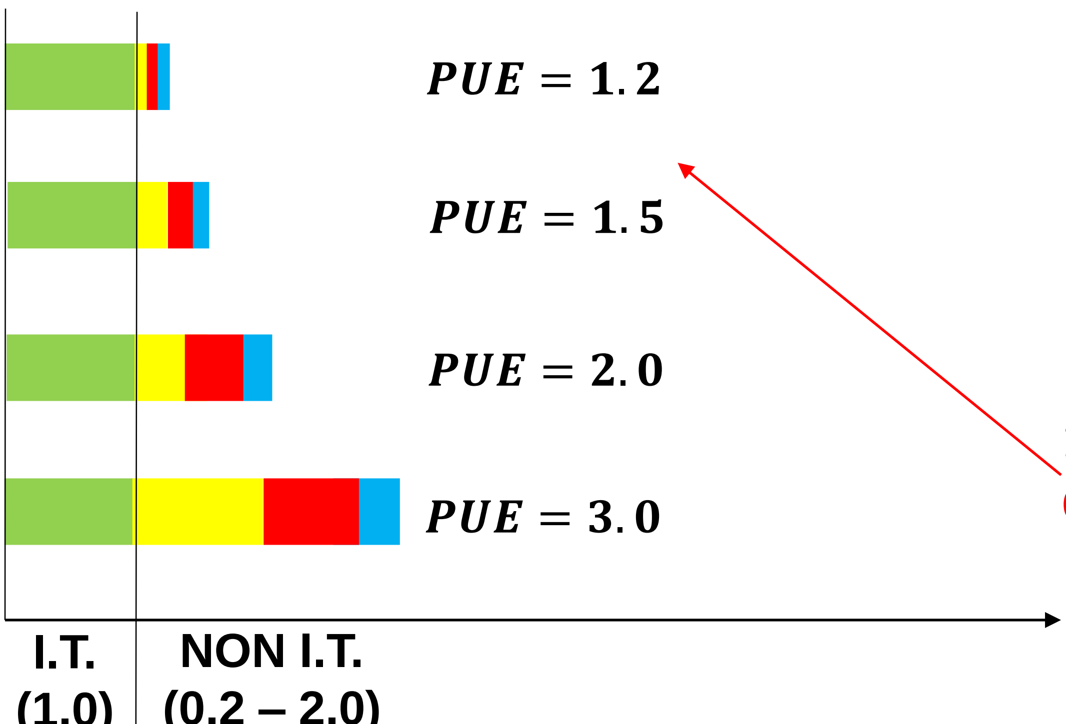
MAJOR LOAD GROUPS

- **LIGHTING**
  - **Higher Efficacy Fixtures**
  - **Automatic Light Reduction Controls**
  - **Design to Lower LPDs**

- **HVAC**
  - **Underfloor Air Supply**
  - **Building Orientation Analysis**

PUE Reduction - Total

$$PUE = 1 + \frac{P_{mech}}{P_{I.T.}} + \frac{P_{elec}}{P_{I.T.}} + \frac{P_{facility}}{P_{I.T.}}$$



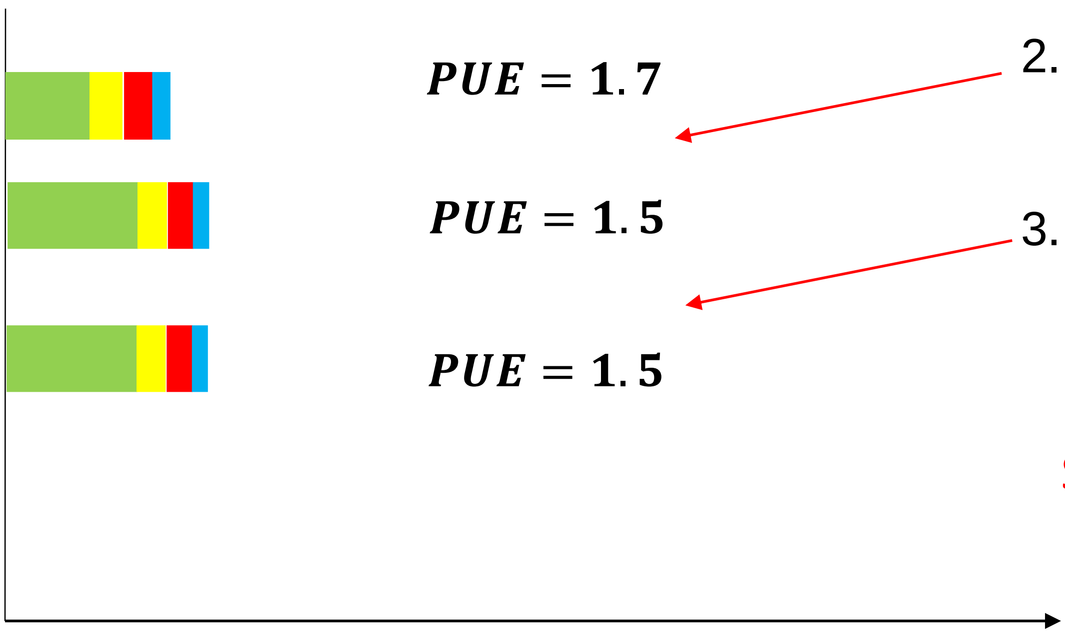
POWER USAGE EFFECTIVENESS in a datacenter is the ratio of TOTAL data center power consumption to the I.T. power consumption.

It is a measure of the "Overhead" power consumption in a datacenter, not used by I.T. equipment.

1.5 TO 1.2 = 20% REDUCTION
OR $260 MILLION ON $1.3B TAB

PUE Limitations

$$PUE = 1 + \frac{P_{mech}}{P_{I.T.}} + \frac{P_{elec}}{P_{I.T.}} + \frac{P_{facility}}{P_{I.T.}}$$



PUE LIMITATIONS

1. Does not account for differences in climate that may affect suitability of some PUE reduction measures.
2. Does not account for efficiencies due to Higher server utilization and other improvements.
3. Does not account for improved machine performance per watt.

ULTIMATELY, PUE AS A METRIC SHOULD BE ONE OF MANY TOOLS USED TO REDUCE OPEX.

Factors that undermine MCF availability

1. OPERATOR ERROR
2. POOR CONSTRUCTION QUALITY
3. LESS THAN THOROUGH COMMISSIONING
4. “ON THE FLY” DECISIONS

Conclusion

RELIABILITY < 100% → MTBF < ∞ → DOWNTIME

LOSS OF REVENUE, DAMAGE TO REPUTATION / BRAND

REDUNDANCY → HIGHER RELIABILITY → HIGHER MTBF

INCREASED CAPEX, LOWER UTILIZATION, EFFICIENCY TRADEOFFS

INNOVATIVE DESIGN → LOWER PUE → LOWER OPEX

INCREASED CAPEX, LOWER UTILIZATION, EFFICIENCY TRADEOFFS

HIGHER AVAILABILITY + LOWER PUE = LOWER TCO

This concludes The American Institute of Architects Continuing Education Systems Course

Tor Kyaagba, PE, CEM