SORAA

AIA Provider Number: 40107394

TM-30: The Science of Color Accuracy

Course Number: SOR30

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Course Description/Overview

When we see an object illuminated by a light source, we see a color. This color corresponds to a point in color space. Colors are characterized by their **hue** (red/yellow/green/blue) and by their **saturation** (from dull to very saturated).

The CRI is the standard for color rendition, but suffers from issues such as inaccuracy—due to outdated color science and a lack of information (only one number to characterize color).

To address these issues, the IES formed a task group which created TM-30. SORAA's scientists led the technical work of TM-30. TM-30 uses state-of-the-art color science and produces more information with higher accuracy about color rendition

TM-30, together with other color quality metrics, is used to design optimal products.

Learning Objectives

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

1. Understand the importance of TM-30 and how it is used to understand color accuracy
2. Understand how to evaluate color quality in LED lamps beyond CRI
3. Understand how TM-30 evaluates color rendition with better science than the CRI did
1. Learn how to identify Rf and Rfh1, for high-fidelity sources, Rg and red saturation, for color-enhancing sources, the whiteness index Rw and chromaticity

IES TM-30 The Science of Color Accuracy

Introduction

The CRI is the standard for color rendition, but suffers from issues:

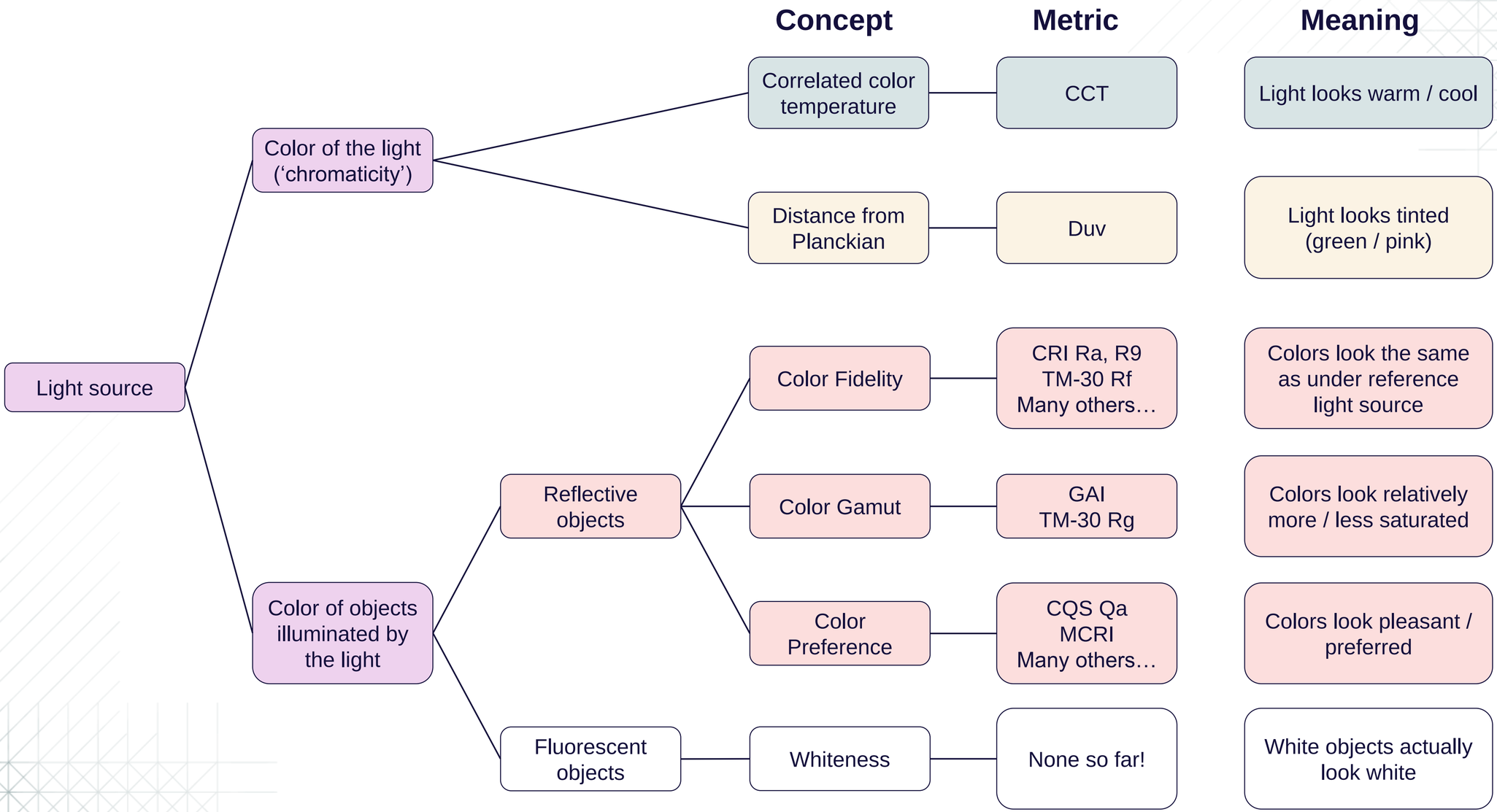
- Inaccuracy—due to outdated color science
- Lack of information (only one number to characterize color)

To address these issues, the IES formed a task group which created TM-30. SORAA's scientists led the technical work of TM-30.

TM-30 uses state-of-the-art color science and produces more information with higher accuracy about color rendition.

SORAA uses TM-30, together with other color quality metrics, to design optimal products.

Many ways to describe a light source:



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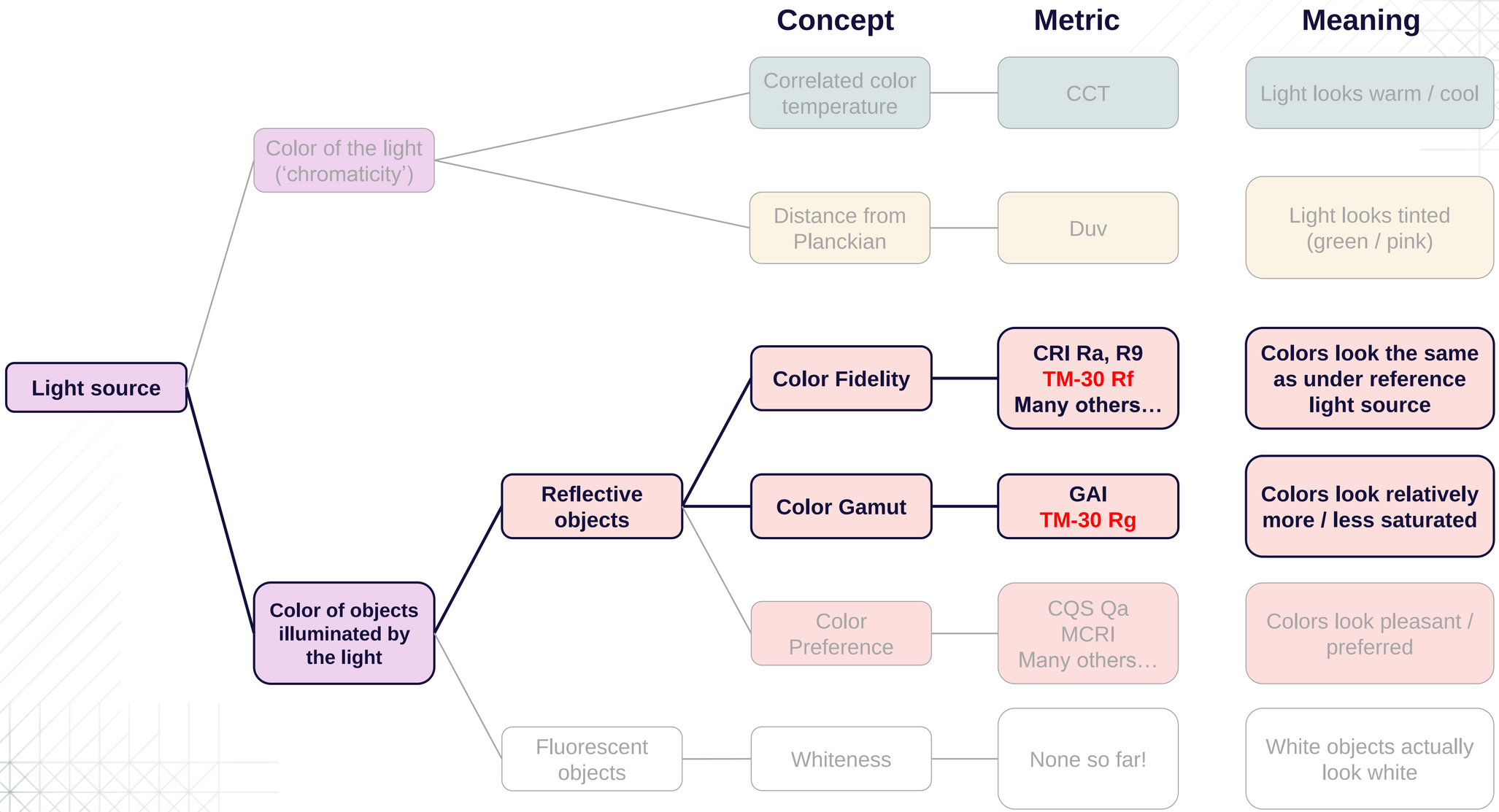
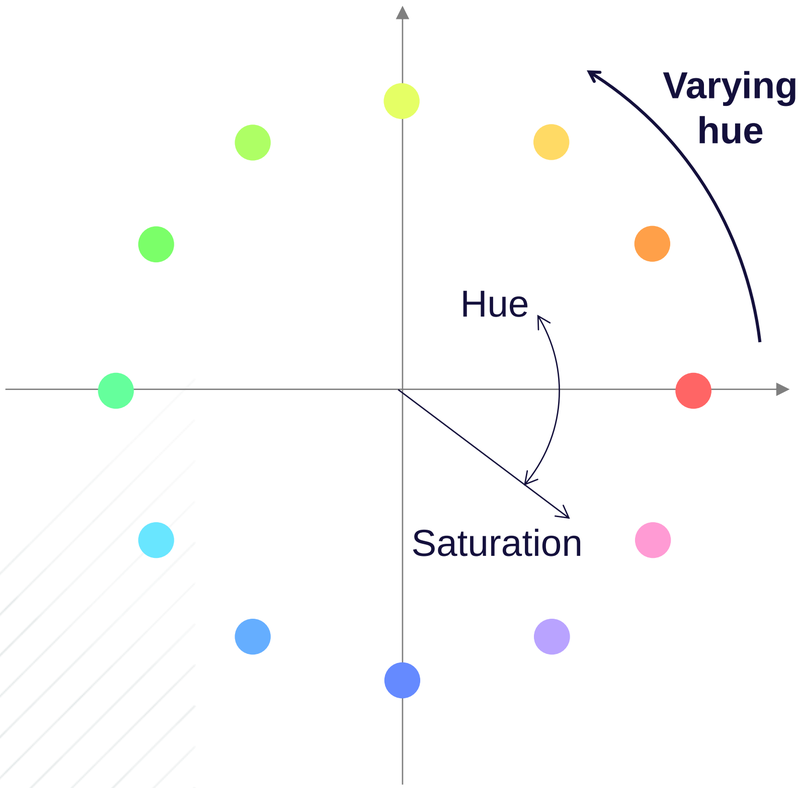


Basics on Color Rendition



Color Space Coordinates

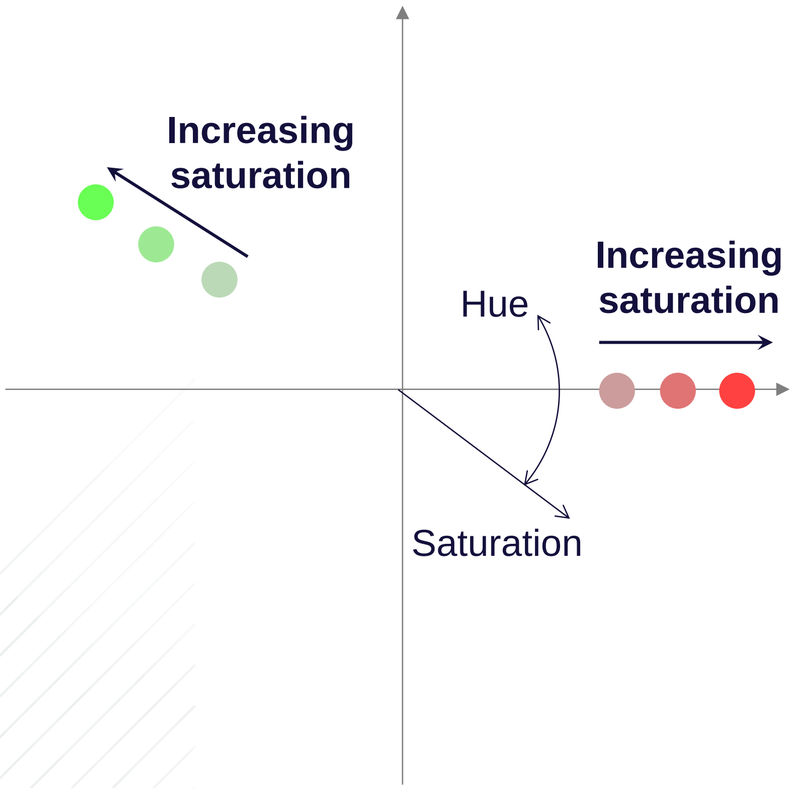
When we see an object illuminated by a light source, we see a color.

This color corresponds to a point in color space.

Colors are characterized by:

- their **hue** (red/yellow/green/blue)

Basics on Color Rendition



Color Space Coordinates

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- their **hue** (red/yellow/green/blue)
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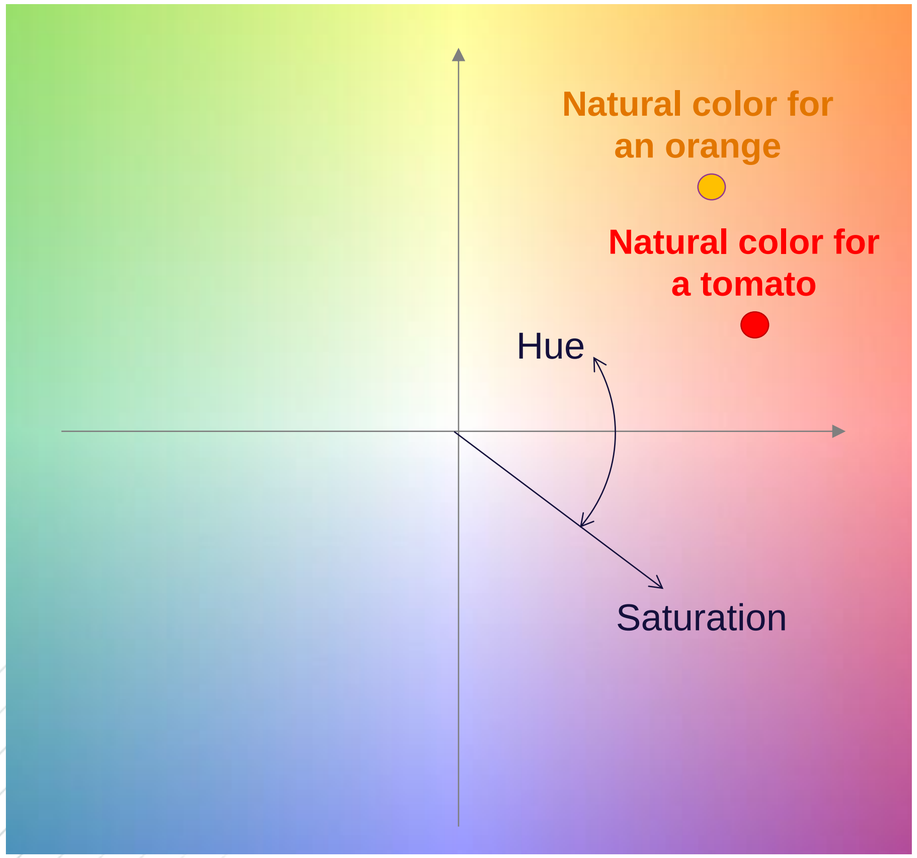
Basics on Color Rendition

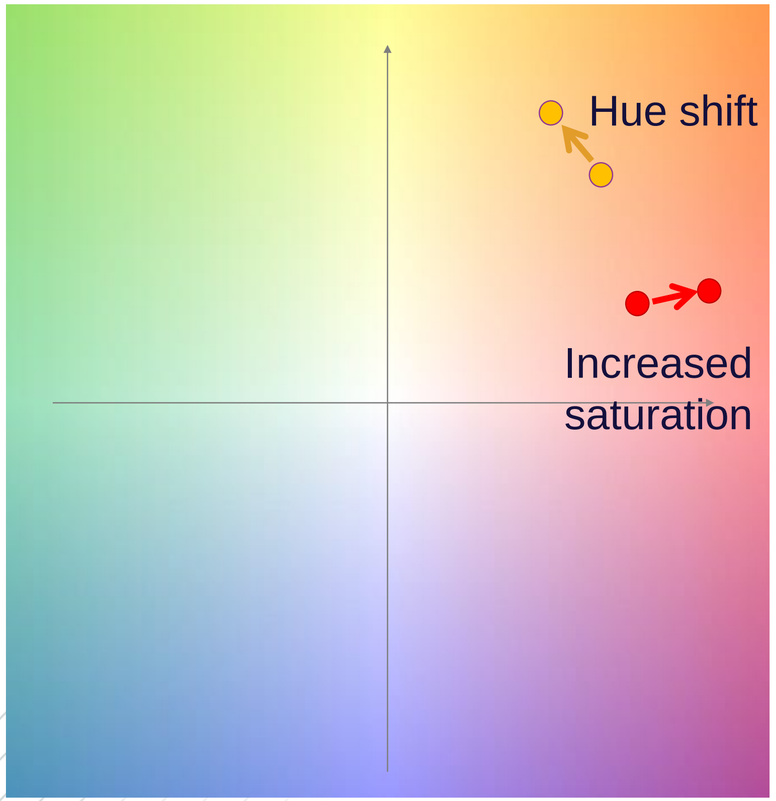


Color Space Coordinates

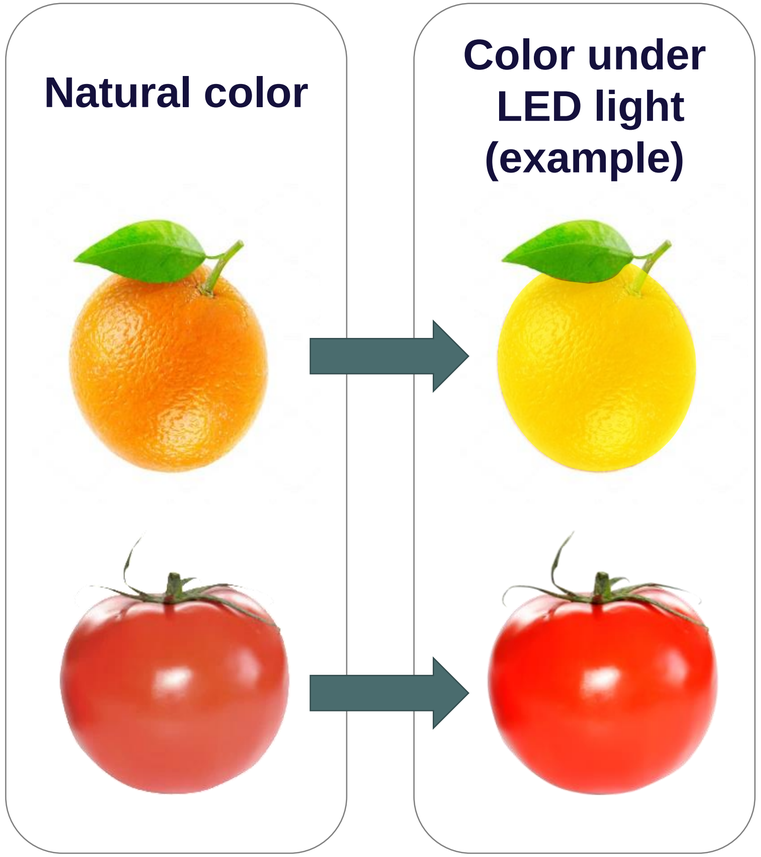
Each color corresponds to a point in color space, and is characterized by its hue and saturation

“Natural color” of an object = its color under natural light (sunlight / incandescent, depending on the CCT)

Basics on Color Rendition



Color Space Coordinates



Corresponding Appearance

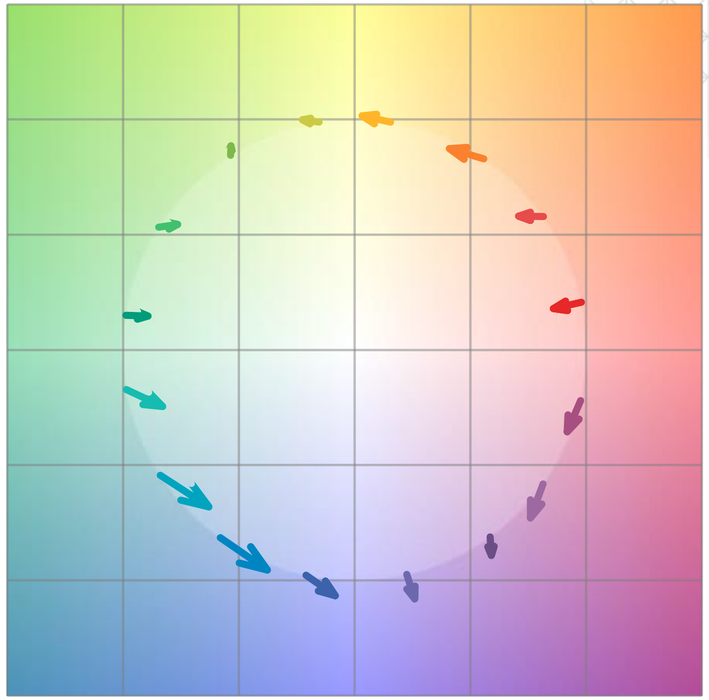
- Artificial light sources can distort colors from their natural appearance
- In general, a light source can modify the hue and/or saturation of objects

TM-30 color icon

If we take a series of colored samples and compute their color distortions under a light source, we get a “map” of how various colors are distorted.

In this example, we have a light source for which:

- red is de-saturated (more dull)
- orange is shifted toward yellow
- cyan is shifted towards blue

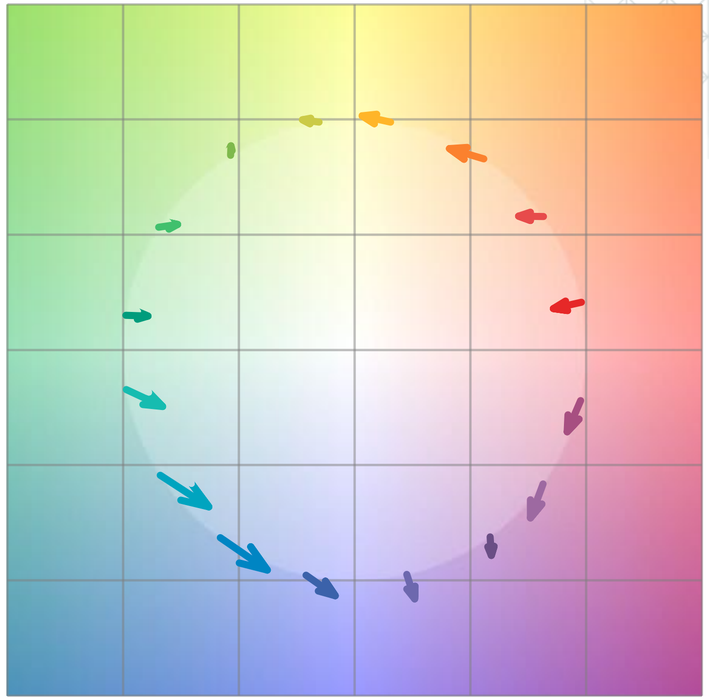


TM-30 color icon

This is precisely how TM-30 works. TM-30 has 99 carefully-chosen color samples. Each arrow is obtained from averaging several samples of similar color.

This diagram is called the **TM-30 color icon**.

It tells us a lot of information about the color rendition of a light source.

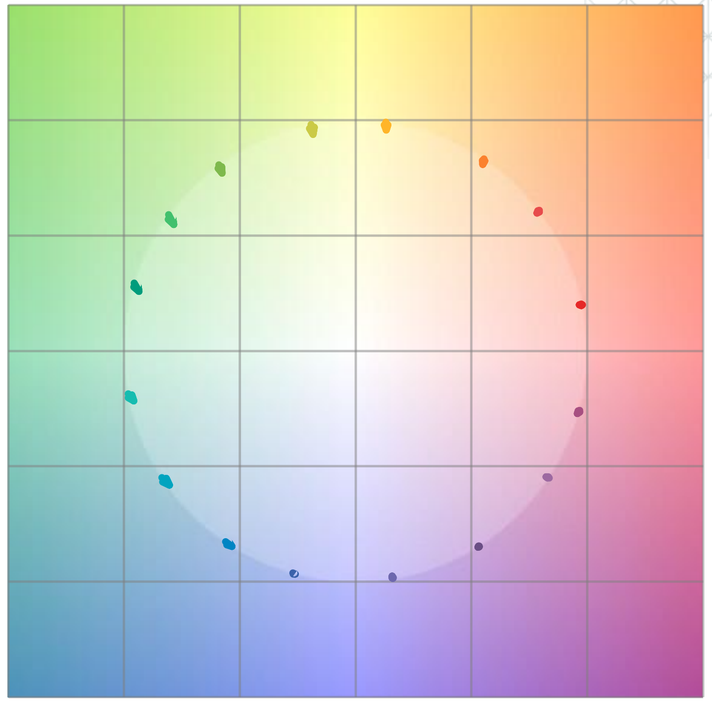


TM-30 color icon – Examples

This light source hardly causes any color distortion: all the arrows are very small.

It is a (nearly-ideal) **halogen** lamp.

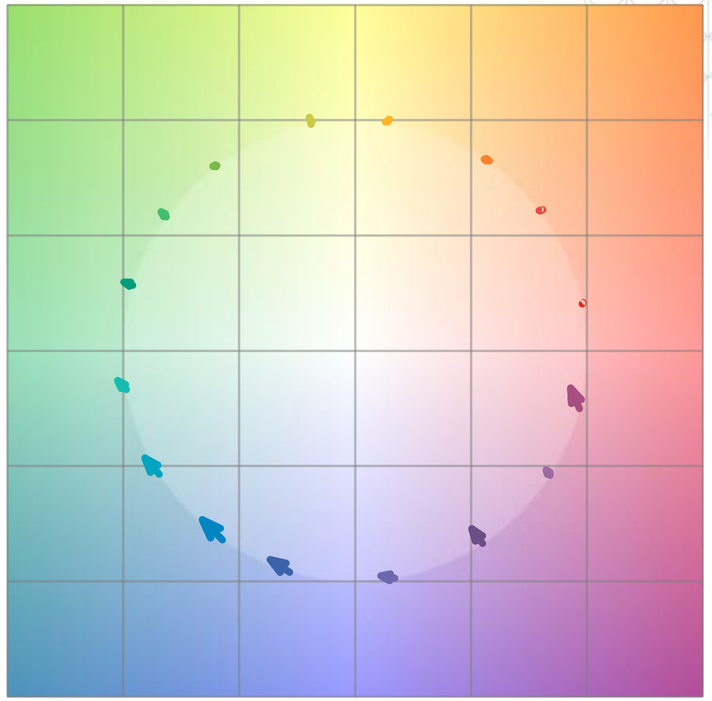
“**Color fidelity**” = the fact of rendering colors naturally. This is a high-fidelity source.



TM-30 color icon – Examples

This light source has small color distortion for blue colors, and no color distortion for red colors

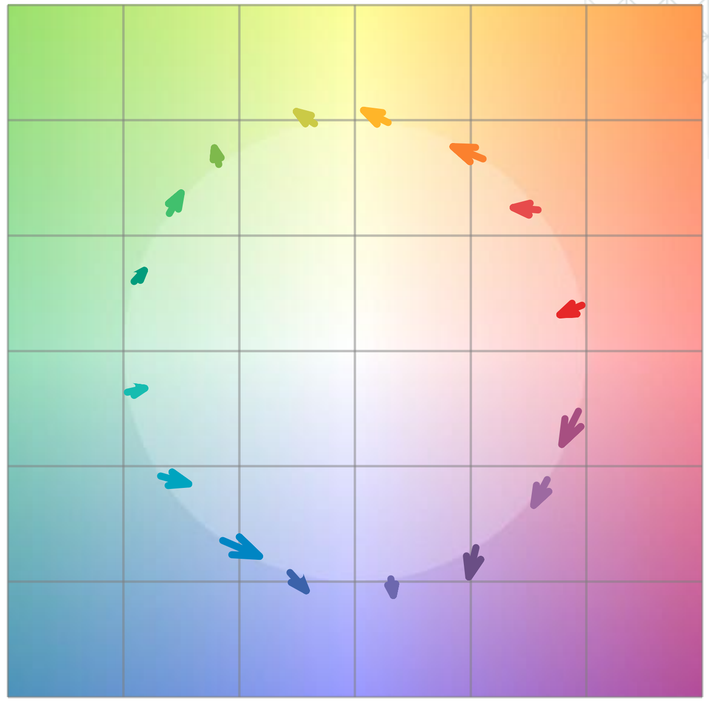
It is a **high-fidelity LED** (with high-CRI and high R9)



TM-30 color icon – Examples

This light source has color distortion for all colors. It makes red and warm colors less saturated.

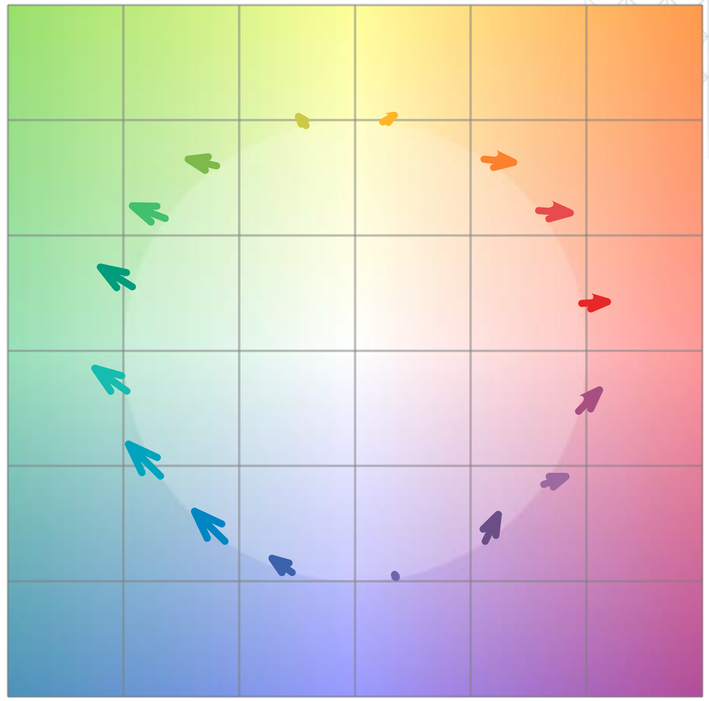
It is a **low-fidelity LED** (low CRI, low R9).



TM-30 color icon – Examples

This light source also has color distortion for all colors. However, it makes red and warm colors **more saturated.**

It is a **“color-enhancing” LED**

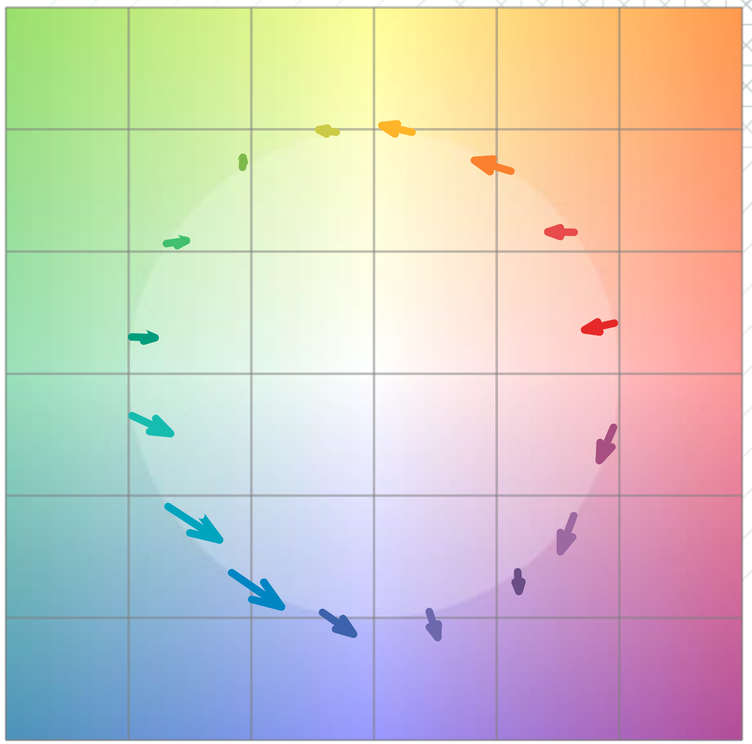


TM-30 Rf

From the icon, TM-30 derives **Rf (color fidelity index)**

Rf describes the average color distortion. It is calculated from the **average length of the arrows**.

- Rf = 100 happens when all the arrows have zero length, i.e. when all the colors are identical to natural colors (Example: halogen lamp)
- Rf decreases when colors become different from natural colors (longer arrows on the icon)
- Rf gives similar information to the CRI, but is more accurate
- There is also a metric for red: Rfh1 (which replaces R9)



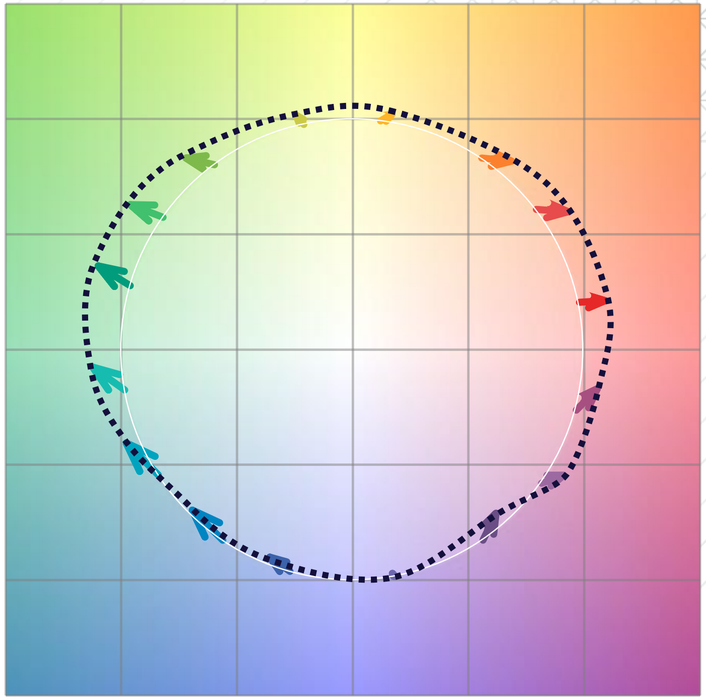
Longer arrows = lower Rf

TM-30 Rg

From the icon, TM-30 derives **Rg (color gamut index)**

Rg describes the increase/decrease in color saturation. It is calculated by connecting the tips of the arrows, and looking at the area of the resulting shape.

- Rg = 100 happens when on average colors are neither over- nor under-saturated
- Rg > 100 happens when, on average, colors are saturated (more vivid)
- Rg < 100 happens when, on average, colors are de-saturated (more dull)



Larger dotted shape = higher Rg

Understanding TM-30 Data

- The color icon tells us what happens to specific colors
- Rf tells us if colors are “natural”, i.e. similar to natural colors (Rf = 100 is the maximum)
- Rg tells us if colors are natural (Rg = 100), saturated (Rg > 100), de-saturated (Rg < 100)
- There is also a “red fidelity index” called Rfh1, which replaces R9

Three Important Classes of Products

1. High-fidelity sources (a.k.a. “high-CRI”)

- Render colors like natural light
- Rf and Rg close to 100
- Useful in a variety of situations where natural colors are sought

2. High-saturation sources (“Color-enhancing”)

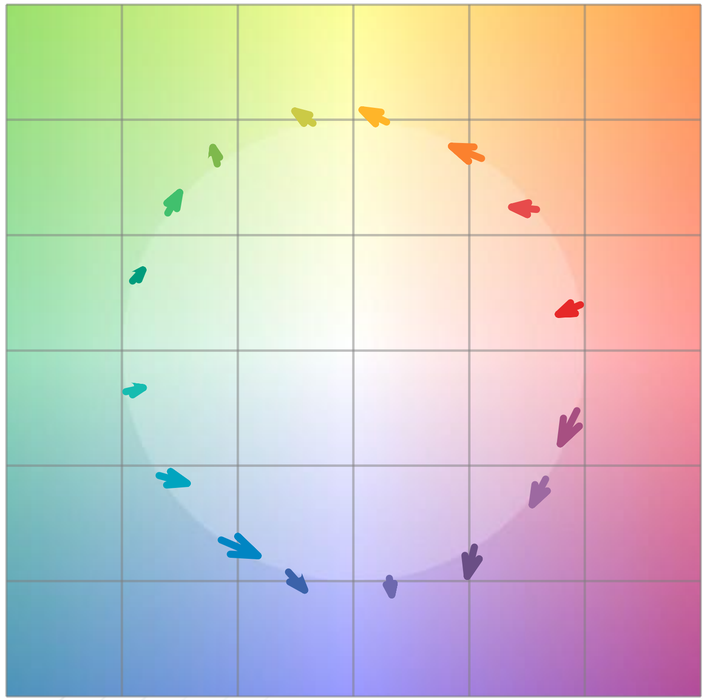
- Increase the vividness of colors
- Have lower Rf, but high Rg (e.g. Rg=110-120)
- Useful in some cases to make colors “pop”

3. Low-saturation sources (most “low-CRI” LEDs)

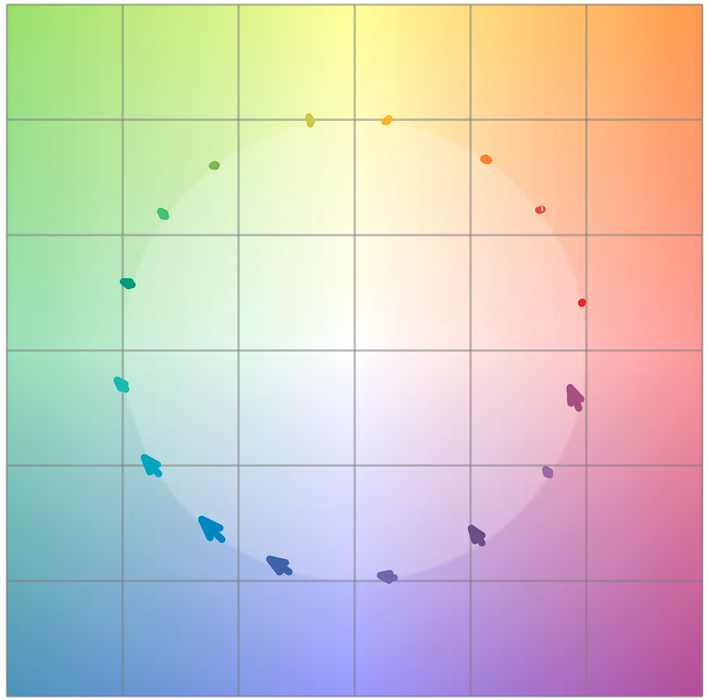
- Makes colors dull and is usually less liked
- Have higher lumens/watts
- Have low Rf and low Rg

Depending on the application, high-fidelity sources or high-gamut sources can be preferable.

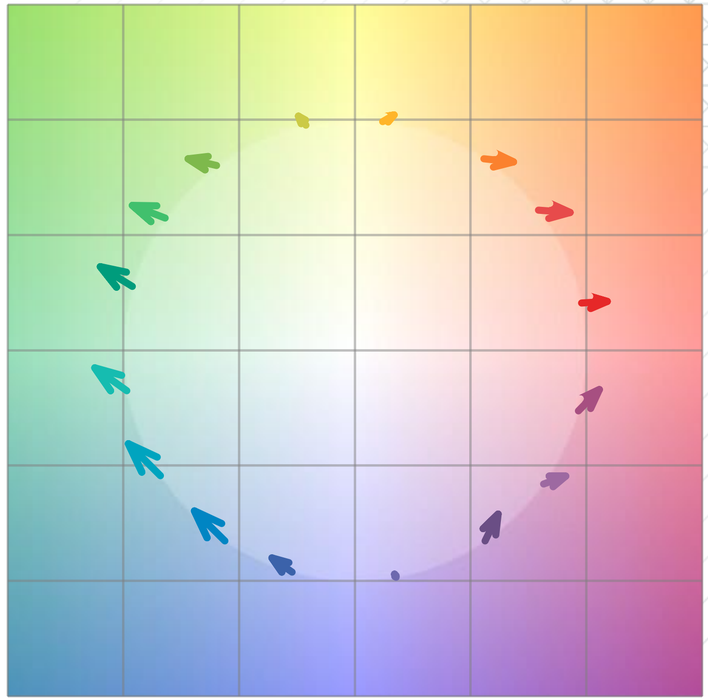
Why the CRI is not enough:
The difference between fidelity and saturation



Low saturation source
Dull colors
CRI = 80, R9 = 0



High fidelity source
Natural colors
CRI = 95, R9 = 95



High saturation source
Saturated colors
CRI = 80, R9 = 0

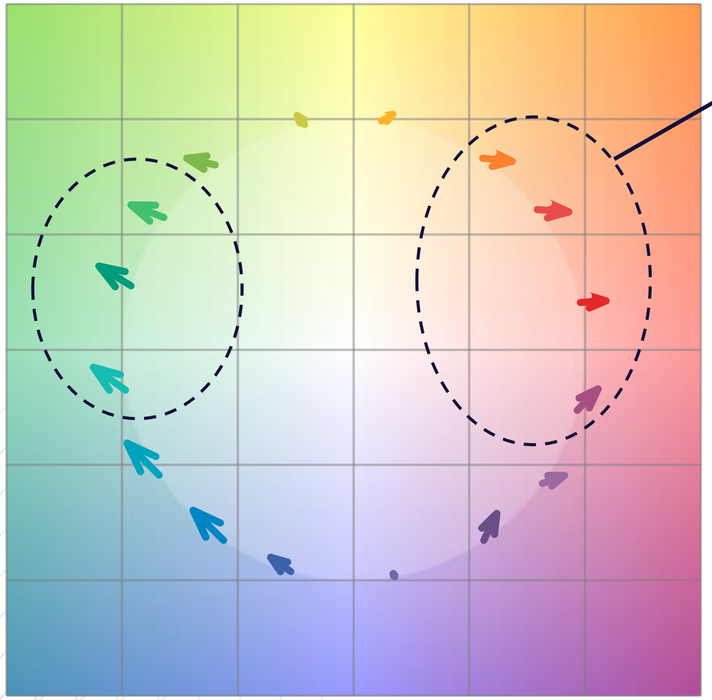
Very often, sources with low R9 have low red saturation (this is bad)
However, color-enhancing sources *also* have low R9 (saturated reds are not accurate, but may be pleasant)

Reading the information of TM-30 - examples

Rf = 78 → This source does not render colors accurately

Rg = 111 → It tends to over-saturate colors

} Color-enhancing source



Specifically, it saturates warm colors (red, orange, pink, skin tones)

…and also green colors (plants and leaves…)

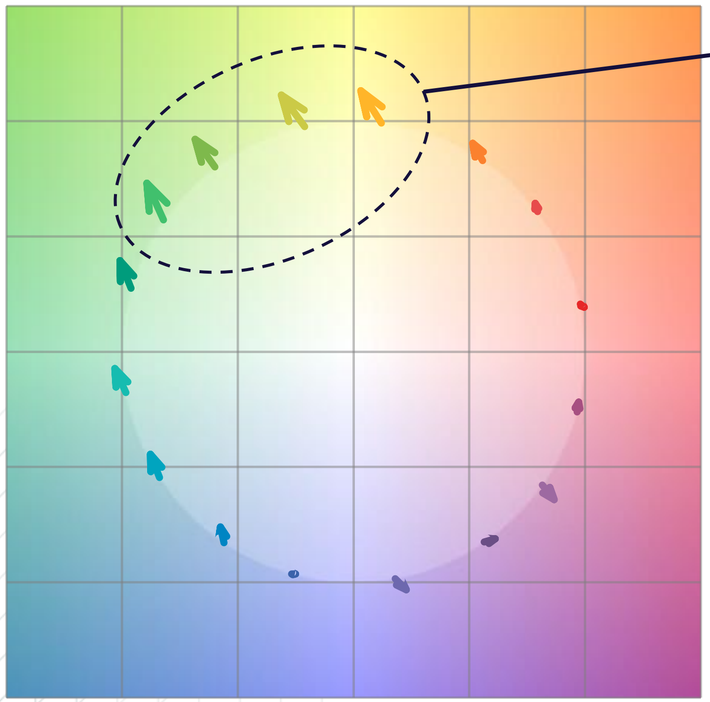
Important note: for “color-enhancing sources”, users should check what colors are enhanced. Very often, **warm colors are what matters most**.

Reading the information of TM-30 - examples

Rf = 84

Rg = 110

Another color-enhancing source…

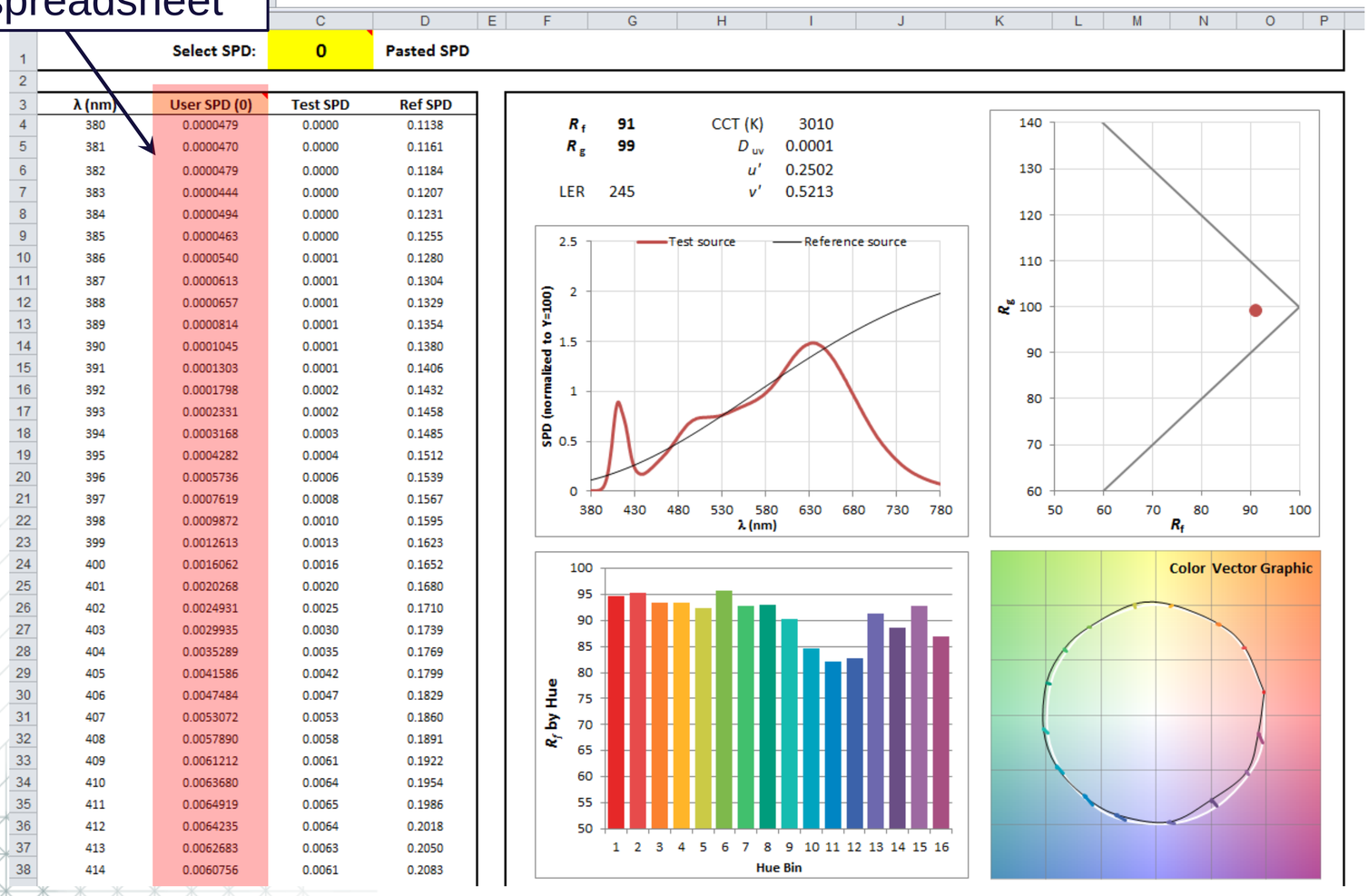


However, this source only saturates yellows

…might be useful in a very specific application, but probably not great in general

How do we calculate TM-30 in practice?

Paste the SPD in the spreadsheet



	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Select SPD:	0		Pasted SPD										
2														
3	λ (nm)	User SPD (0)	Test SPD	Ref SPD										
4	380	0.0000479	0.0000	0.1138										
5	381	0.0000470	0.0000	0.1161										
6	382	0.0000479	0.0000	0.1184										
7	383	0.0000444	0.0000	0.1207										
8	384	0.0000494	0.0000	0.1231										
9	385	0.0000463	0.0000	0.1255										
10	386	0.0000540	0.0001	0.1280										
11	387	0.0000613	0.0001	0.1304										
12	388	0.0000657	0.0001	0.1329										
13	389	0.0000814	0.0001	0.1354										
14	390	0.0001045	0.0001	0.1380										
15	391	0.0001303	0.0001	0.1406										
16	392	0.0001798	0.0002	0.1432										
17	393	0.0002331	0.0002	0.1458										
18	394	0.0003168	0.0003	0.1485										
19	395	0.0004282	0.0004	0.1512										
20	396	0.0005736	0.0006	0.1539										
21	397	0.0007619	0.0008	0.1567										
22	398	0.0009872	0.0010	0.1595										
23	399	0.0012613	0.0013	0.1623										
24	400	0.0016062	0.0016	0.1652										
25	401	0.0020268	0.0020	0.1680										
26	402	0.0024931	0.0025	0.1710										
27	403	0.0029935	0.0030	0.1739										
28	404	0.0035289	0.0035	0.1769										
29	405	0.0041586	0.0042	0.1799										
30	406	0.0047484	0.0047	0.1829										
31	407	0.0053072	0.0053	0.1860										
32	408	0.0057890	0.0058	0.1891										
33	409	0.0061212	0.0061	0.1922										
34	410	0.0063680	0.0064	0.1954										
35	411	0.0064919	0.0065	0.1986										
36	412	0.0064235	0.0064	0.2018										
37	413	0.0062683	0.0063	0.2050										
38	414	0.0060756	0.0061	0.2083										

All you need to compute TM-30 values is:

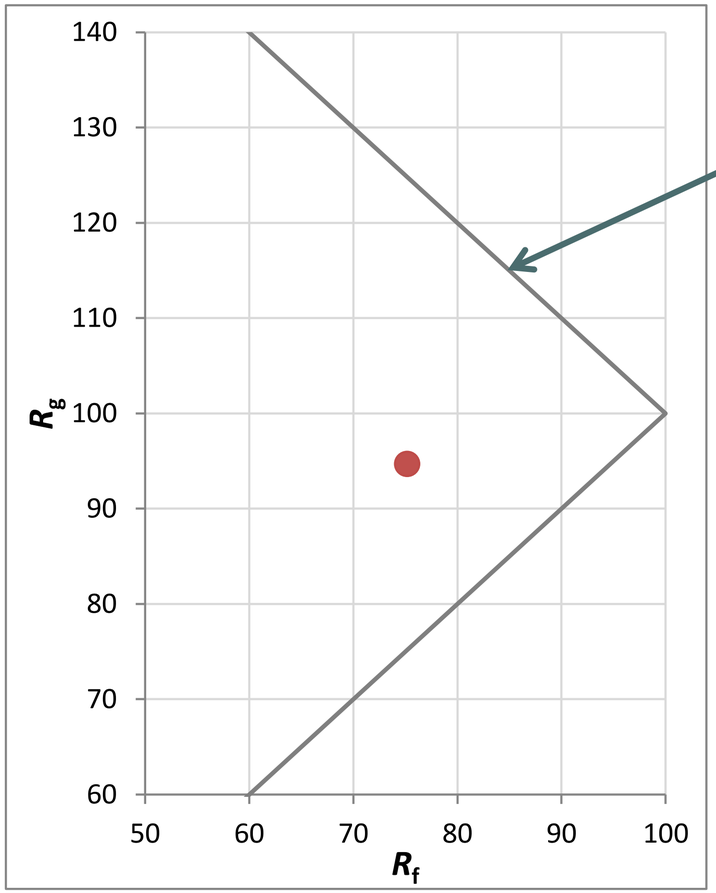
The SPD you are interested in (from a manufacturer spreadsheet, or a hand-held spectrometer)

The IES TM-30 spreadsheet (comes with the TM-30 document, sold by the IES)

The TM-30 spreadsheet: reading results

In addition to Rf, Rg and the color icon, TM-30 displays a variety of results:

The Rf-Rg graph shows both Rf and Rg and illustrates the trade-off between the two: high values of Rf constrict Rg to a specific range



The gray line shows the maximum / minimum possible value of Rg for a given Rf

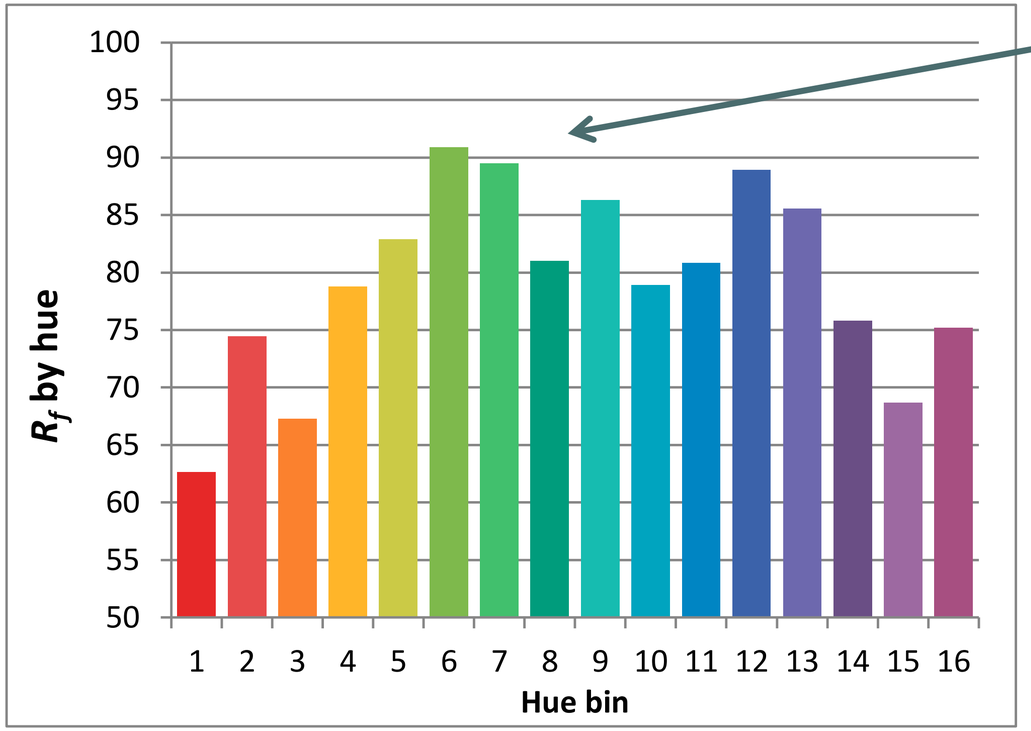
In this example, the light source has a low fidelity index and a slightly low gamut index

The TM-30 spreadsheet: reading results

In addition to Rf, Rg and the color icon, TM-30 displays a variety of results:

The fidelity bar chart shows the fidelity index for all 16 bins.

Rf is (approximately) the average of these 16 values.

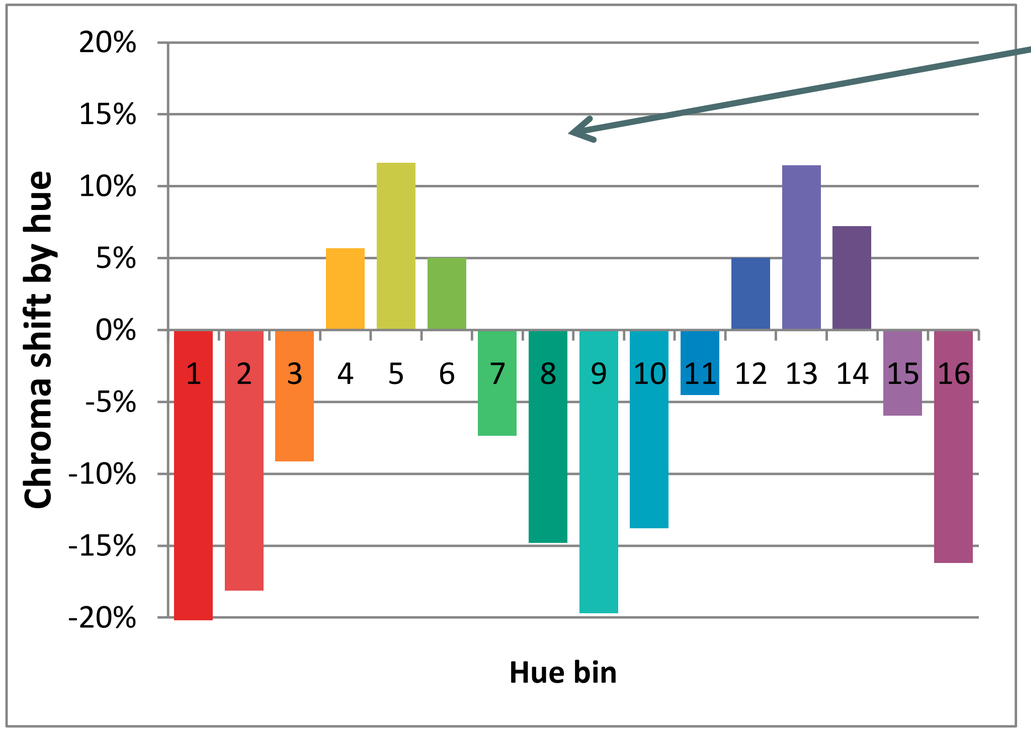


In this example, some greens and blues are accurately rendered, but reds are very distorted

The TM-30 spreadsheet: reading results

In addition to Rf, Rg and the color icon, TM-30 displays a variety of results:

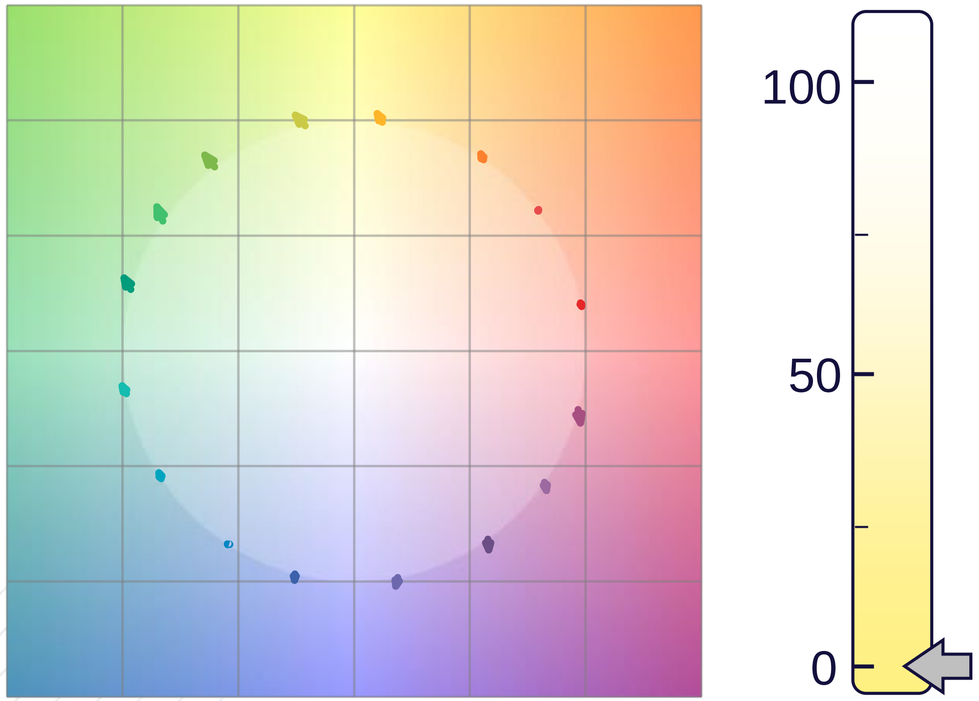
The saturation bar chart shows the change in chroma (i.e. in saturation) for all 16 bins.



In this example, some reds and greens are de-saturated, whereas yellows and blues are over-saturated

Remember - TM-30 is only part of the story

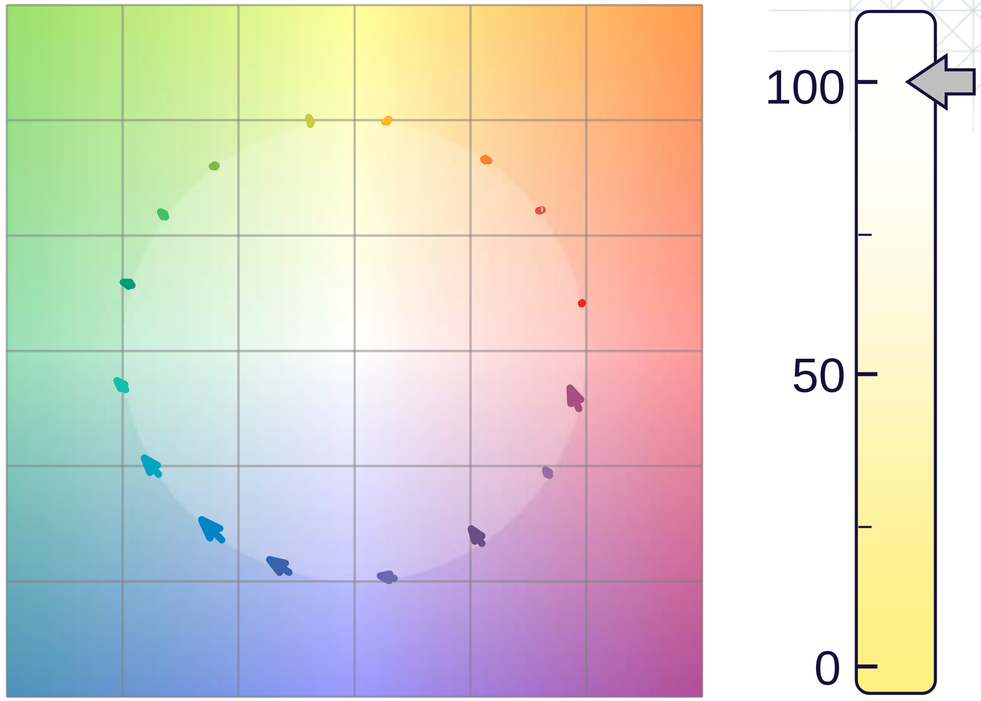
For instance, not all high-fidelity sources are equal…



Rf = 93

Rw = 0 (whiteness index, not part of TM-30!)

No rendering of white objects



Rf = 93

Rw = 100

Accurate rendering of colors and whites

Summary

Light sources can modify color in various ways:

hue shift and saturation change.

TM-30 evaluates color rendition with better science than the CRI did.

It generates a variety of information: Rf (and Rfh1), Rg, color icon. These give advanced user more insight in the color rendition of a source.

Summary

Remember: TM-30 tells you about object colors, which is **only one aspect** of the quality of light. To fully evaluate a light source, users should look at:

- CCT + chromaticity (for the color of the light itself)
- TM30 Rf and Rfh1 (for high-fidelity sources)
- TM30 Rg (for color-enhancing sources)
- TM30 icon (to know about specific colors)
- Whiteness index Rw (for whites rendering)