Modeling Future EP Trends – Three Laws of Energy Proportionality Growth

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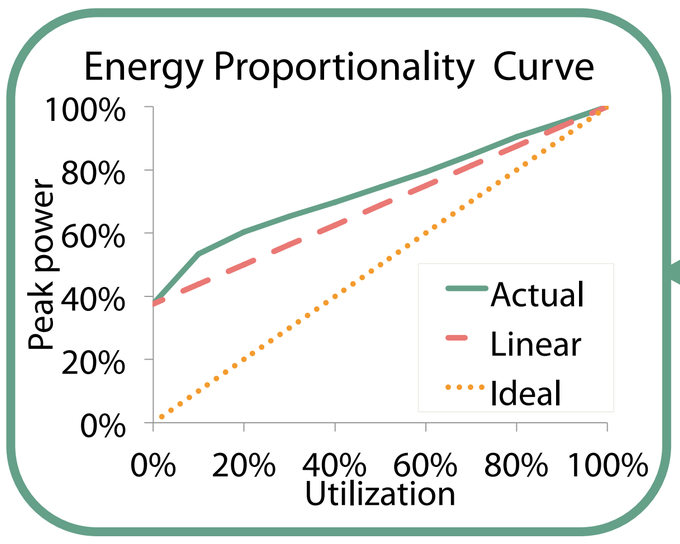
Measuring Energy Proportionality



Energy Proportionality

$$EP = 1 - \frac{Area_{actual} - Area_{ideal}}{Area_{ideal}}$$

Dynamic Range

$$DR = \frac{Power_{peak} - Power_{idle}}{Power_{peak}}$$

Linear Deviation

$$LD = \frac{Area_{actual}}{Area_{linear}} - 1$$

D. Wong and M. Annavaram, "Knightshift: Scaling the energy proportionality wall through server-level heterogeneity," in Proceedings of the 45th Annual IEEE/ACM International Symposium on Microarchitecture, MICRO-45 '12, 2012

First Law

Energy Proportionality is a function of both dynamic range and linear deviation

$$EP = DR - LD(2 - DR)$$

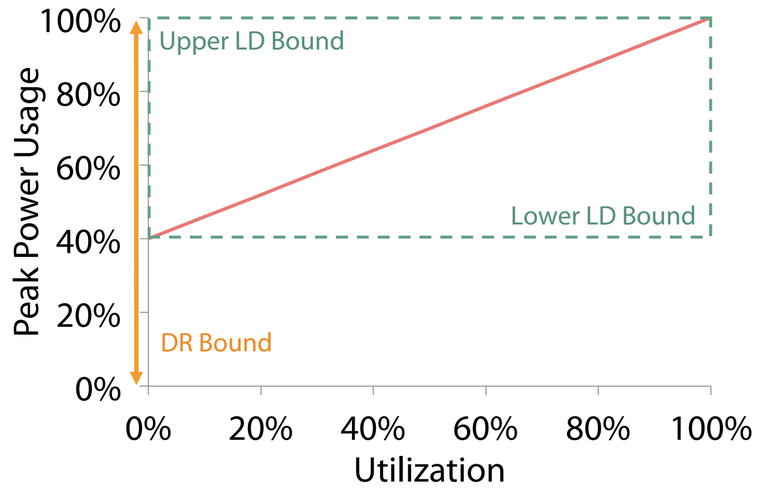
Second Law

There exists an *absolute theoretical bound* on the values of EP, DR, and LD

$$EP \rightarrow (0, 2\,DR)$$

$$DR \rightarrow [0, 1]$$

$$LD \rightarrow \left(\frac{2 - 2\,DR}{2 - DR} - 1, \frac{2}{2 - DR} - 1\right)$$



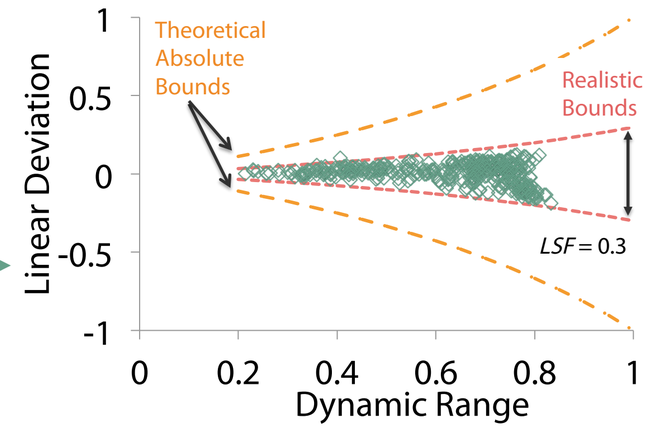
Third Law

In reality, there exists a *realistic bound* on the values of EP and LD, limited by the *LSF*. Historically, **LSF=0.3**.

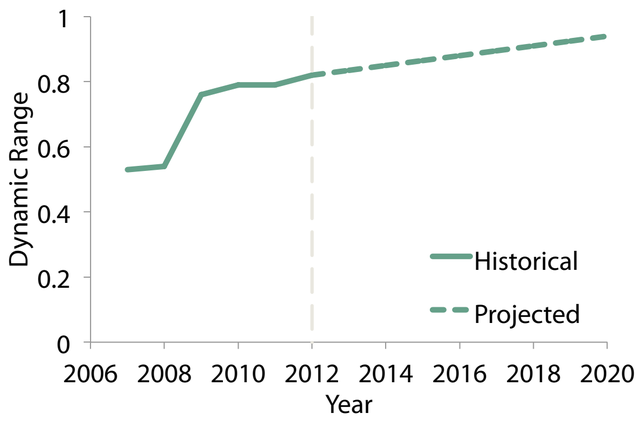
$$EP \rightarrow (0, (1 + LSF)\,DR)$$

$$LD \rightarrow \left(LSF\left(\frac{2 - 2\,DR}{2 - DR} - 1\right), LSF\left(\frac{2}{2 - DR} - 1\right)\right)$$

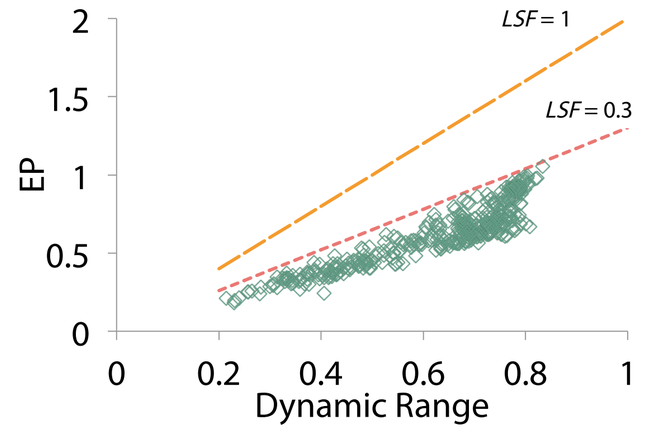
LSF = Linear Deviation Scaling Factor

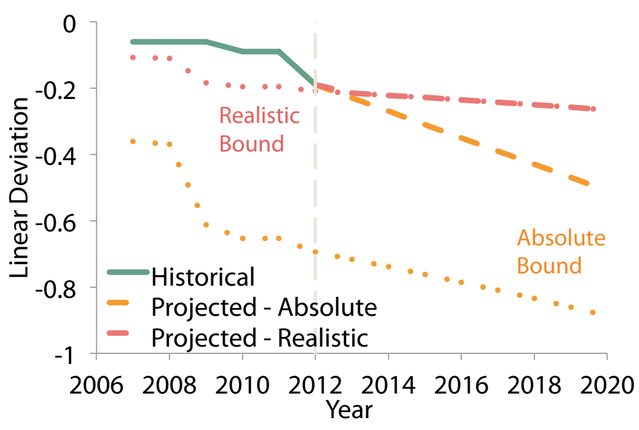


Projecting Future EP/LD/DR Trends



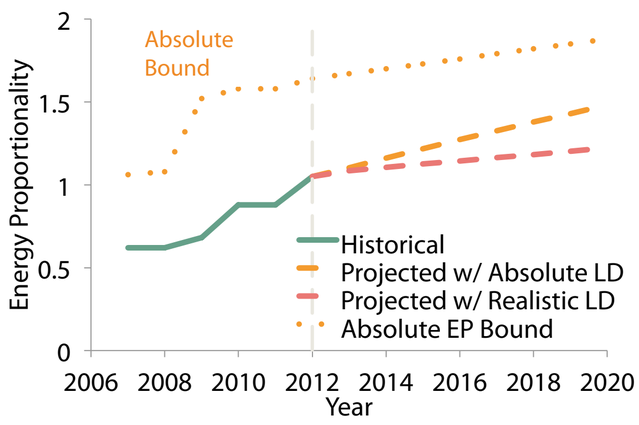
We optimistically assume that dynamic range will continue to improve by **1.5% per year**





We assume that LD will improve at **-0.04 per year**

But, by 2013 we would hit the realistic bound, limiting LD improvement to **less than -0.01 per year**



It is projected that EP will only improve by **16% by the end of the decade** under realistic assumptions (**down from 43%** under absolute bounds)

Implications

LSF < 1 due to lack of EP in non-processor component

The key to sustaining EP growth is through EP improvements to non-processor components.

If LSF improve to 0.6, then EP can grow to 1.4 (vs 1.2 for LSF = 0.3) by the end of the decade

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