Hitting your Numbers

1) What numbers?
   a) Volume
   b) Original Gravity
   c) IBU
   d) Mash Efficiency
   e) Boil-off rate
   f) Final Gravity

2) How to measure your numbers
   a) Volume
      i) NOTE: The volume of liquid will increase about 4% as it comes up to boiling temp.
      ii) If your pot has a fancy sight glass, your done
         (1) Sensitive to temperature
      iii) Yard stick + math
         (1) Measure pot diameter and height of liquid in inches using a yardstick
         (2) Volume (Gallons) = (Height x π x r^2) / 231
         (3) For example, I know on my pot 1" = 0.64 gallons, so 9 1/2" = 6.08 Gallons
         (4) Sensitive to temperature
      iv) Weight
         (1) 1 gal = 8.34 lb
         (2) Very accurate, but hard to measure a hot pot full of sticky wort
         (3) Not sensitive to temperature
         (4) Hard to measure hot/boiling liquids
         (5) Need scale that is accurate in 0-70 lb range for 5 gal batches
      v) Measure, fill, mark
         (1) Measure out small amounts of liquid, add to the vessel, and mark the vessel at each point
         (2) Not very accurate, prone to error
         (3) Sensitive to temperature
         (4) Hard to guess levels in between marks
      vi) Personally, I use weight for cold liquids and a yardstick for boiling liquids. I tend to ignore the 4% hot/cold difference.
   b) Gravity
      i) Hydrometer
         (1) Pro
            (a) Cheap
            (b) Accurate if used correctly
            (c) Can accurately measure Final Gravity
         (2) Cons
            (a) Need to cool liquid before measuring
               (i) I like to keep a metal bowl in the freezer then pour hot wort into it to chill it down fast
            (b) Need to apply temperature adjustment if liquid temp doesn't match hydrometer calibration temp
            (c) Needs a lot of liquid

ii) Refractometer
    (1) Pro
        (a) Very accurate
        (b) Built in temperature calibration, no need to chill sample
        (c) Only uses a few drops
        (d) Fast
    (2) Cons
        (a) Expensive
        (b) Measuring final gravity is very accurate
    (3) TIP: The temperature calibration can take a minute or two as the temps in the refractometer stabilize.

c) IBU
    i) Unfortunately the only way to measure IBU is with a spectrophotometer https://phdinbeer.com/2014/09/16/beer-chemistry-1-measuring-ibus-in-beer/
    ii) Very Expensive

d) Mash efficiency
    i) http://howtobrew.com/book/section-2/what-is-malted-grain/mash-efficiency
    ii) https://www.brewersfriend.com/brewhouse-efficiency/
    iii) Note: it's common for efficiency to vary by
        (1) Grain crush size
        (2) Mash volume / Original gravity / grain weight
        (3) Water to Grist ratio

e) Boil-off rate
    i) https://www.morebeer.com/content/boil_off_rate_calculator
    ii) Note: this can vary by
        (1) Weather
        (2) Pot Diameter
        (3) Burner
        (4) Propane tank fullness
        (5) Phase of moon

3) What numbers actually matter and why?

a) Original Gravity
    i) Gravity and IBU balance against each other
    ii) Too high O.G
        (1) Beer won't be hoppy enough and will be unbalanced
        (2) Finishing gravity too high. Yeast have a limited attenuation and may not give your the final dryness you want
    iii) Too low O.G means the beer will be too hoppy, and may be thin due to lower final gravity
    iv) Original Gravity determines
        (1) Alcohol
        (2) Body and Mouthfeel

b) Volume
    i) Effects gravity and IBU
    ii) Too much volume and your gravity will be low, ibu will be low beer will be thin
    iii) Too low a volume and gravity will be high, ibu will be high
    iv) One hop pellet in 1oz is a lot more bitter than one hop pellet in 5 Gallons

c) IBU

        i) Bitterness balances malt sweetness
        ii) If you can't consistently hit an IBU target, it's hard to formulate recipes
            (1) Beer may be bitter one time and not the next time
    d) Mash efficiency
        i) Really only matters for commercial brewers where cost is important
        ii) Effects how much grain you buy
        iii) You want to know roughly what your efficiency is
        iv) Brewing is easier if you formulate your recipe with an efficiency lower that what you actually get.
            (1) See below, but it's easier to dilute with water than to add more sugar
    e) Boil-off rate
        i) Recipe will expects a boil-off rate usually around 14%
        ii) https://www.morebeer.com/content/boil_off_rate_calculator
        iii) If you don't boil hard enough (compared to recipe) you'll end up with a lower gravity, higher volume, and lower IBU
            (1) If this happens you're kind of stuck. If you boil longer to reduce the volume, you'll throw off IBU number. If you add DME/LME, your IBU number will be off.
        iv) If you boil harder (compared to recipe) you'll end up with a more concentrated wort, lower volume, and higher IBU
            (1) See below, but it's easy to add water to compensate
    f) Final Gravity
        i) Ensures you fermented to completion and have the proper amount of residual sugars
        ii) Also balances against IBU

How to hit your numbers:
1) IBU
    a) Adjust hops for the actual Alpha Acid of your hops
        i) If recipe calls for 1oz of hops that are 10%AA and your hops are 5% AA
            (1) Target weight = Recipe Weight * Recipe AA / Hop AA
            (2) So: 1oz*10/5 = 2oz to reach recipe bitterness level
    b) Ensure your volume is correct, see volume below
2) Final Gravity
    a) Lots of happy healthy yeast
    b) Ramp fermentation temp to push yeast to dry out beer
    c) Do a force fermentation to determine your lowest possible gravity
        i) https://www.winning-homebrew.com/forced-fermentation-test.html
    d) Hit your mash temps
        i) Be consistent with how you measure mash temperature
        ii) The mash is a temperature gradient and will have different temps and different locations
        iii) A temp probe inserted sideways into vessel may have different temperature depending on grain amount
        iv) In the end, get as close as you can, but don't worry
    e) Good yeast is more important that hitting mash temps
        i) http://brulosophy.com/2015/10/12/the-mash-high-vs-low-temperature-exbeeriment-results/

    f) For me, I've never had good success adding hot water to grain and hitting a target temp. So I gave up and went to a mash system where I can step mash and control temps. If I'm off, I can adjust.
    g) If you have tips send them in!
3) Gravity/Volume
    a) You have two opportunities to fix your numbers:
        i) Pre-boil
            (1) At this point you can fix a lot and fixing it here will set you up for success
        ii) Post-boil
            (1) At this point you can only add water
    b) Dilution/Evaporation equation
        i) You can exchange gravity for volume
            (1) Increase volume by adding water, reduces gravity
            (2) Decreasing volume, by boiling, increases gravity
            (3) Assuming a well stirred pot, removing volume, doesn't increase or decrease gravity
        ii) Starting Gravity Units * Starting Volume = Ending Gravity Units * Ending Volume
        iii) A Gravity unit is
            (1) (S.G - 1) * 1000
            (2) So 1.090 = 90, 1.075 = 75, etc
        iv) Using the maths:
            (1) Ending Gravity Units = Starting Gravity Units * Starting Volume / Ending Volume
            (2) Ending Volume = Starting Gravity Units * Starting Volume / Ending Gravity Units
4) Examples
    a) Let's say you're shooting for: Pre-boil Gravity of 1.070 and 7 gallons
    b) Case 1: Pre-boil gravity too high
        i) Your pre-boil measurement is 1.090 and 7 gallons
            (1) Ending volume = 90 * 7 / 70 = 9 Gallons
            (2) So add 2 Gallons of water to get to 1.070
            (3) Stir and remove 2 gallons to get 1.070 @ 7 gallons
    c) Case 2: Pre-boil gravity too low
        i) Your pre-boil measurement is 1.050 and 7 gallons
            (1) Boil method:
                (a) Ending Volume = 50 * 7 / 70 = 5 gallons
                (b) Boil until the volume is 5 gallons
                (c) You will need to adjust hop rates for the new reduced batch size
            (2) Add DME/LME to reach 1.070 and 7 gallons
                (a) DME is 45 points per lb per gallon
                (b) LME is 37 points per lb per gallon
                (c) So total points of recipe: 75 GU * 7 gal = 490 points, and measured was 350, so you need 140 more points
                (d) So 140/45 = 3.1 lb DME
                (e) Or 140/37 = 3.78 lb LME
    d) Case 3: Pre-boil volume too high
        i) Your pre-boil measurement is 1.070 and 9 gallons
        ii) Stir the wort thoroughly and remove 2 gallons
    e) Case 4: Pre-boil volume too low
        i) Your pre-boil measurement is 1.070 and 5 gallons

        ii) Live with the reduced volume
            (1) Adjust hops for new batch size
        iii) Or add 2 gallons of water to get to 7 gallons
            (1) This will lower the gravity to 1.050 (70*5/7) at 7 Gallons
            (2) Then add 3.1 lb DME to bring gravity up to 1.070
    f) Case 5: Everything is off
        i) Your pre-boil measurement is 1.080 and 8 gallons
        ii) First, dilute with water to hit 1.070
            (1) 80 * 8 / 70 = 9.1 Gallons, so add 1.1 gallons
        iii) Now stir well and remove 2.1 Gallons
    g) Case 6: Everything is off 2
        i) Your pre-boil measurement is 1.050 and 5 gallons
            (1) Add 2 gallons of water to get to 7 gallons
                (a) You should end up with 7 gallons at 1.035
            (2) Add 5.4 lb DME
    h) Case 7: you hit your pre-boil number and post boil volume is low and gravity is high
        i) Since you hit your pre-boil numbers, the amount of sugar in the pot is right, you just need to replace some of the water that was lost
        ii) So if your pre-boil was 1.070 and 7 gal, and your post-boil is supposed to be 6 gal at 1.082
        iii) If you have 5 gal at 1.098, then add 1 gal of water and you should hit your number.
5) Recommendations
    a) If your mash efficiency is about 80%, target your recipe for ~75%
        i) You'll always have too much sugar out of your mash and diluting with water is easier than adding DME/LME
        ii) The actual efficiency number doesn't matter as long as your recipe was computed for a higher efficiency
        iii) Yes, this means you technically bought too much grain, but it also means you don't have to measure your mash/sparge water to the fraction of an ounce. And it means you don't have to keep a ton of extract on hand.
    b) Boil more aggressively than your recipe expects
        i) Boiling only removes water and doesn't remove sugar
        ii) If you hit your pre-boil number and boil more aggressively, then it just means you lost more water than desired and it's easy to add it back in.
    c) Make more than you need
        i) Your total post boil volume should fill your carboy with extra to spare.
        ii) If your carboy holds 5.5 gallons, make 6 gallons of wort and throw half a gallon away.
    d) Pre-boil Volume, and Gravity are key
        i) Dial these in and your post-boil adjustment will be easier