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A COMPARATIVE STUDY OF RESIDENTIAL HOUSEHOLD ENERGY CONSUMPTION IN AUSTRALIA AND THE USA

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ABSTRACT

The residential households utilise approximately one-fifth of the total energy consumed in the developed counties especially in the U.S. and Australia. The rate of household energy consumption is growing each year as the number of residential dwellings and expectation of life style has increased. The use of electricity has been rising since long. As the large proportion of the energy consumed by the residential households is electricity which is the most greenhouse gas-intensive form of delivered energy in the U.S. and Australia, the residential household is responsible for enormous greenhouse gas emissions. Therefore, the primary objective of this paper was to conduct a comparative analysis of household energy consumption pattern both in the U.S. and Australia for the period of 1990 to 2008. The study revealed that the per capita energy consumption by the residential households in Australia is significantly higher than the households energy use in the U.S. The electricity consumption has increased in both countries however the gas consumption has notably increased in Australia while the U.S. residential household gas consumption is steady.

Keywords: Residential household, energy, electricity, gas, heating & cooling

1 INTRODUCTION

Energy becomes a fundamental need for human settlements right from construction, (roads, buildings, building materials and infrastructure), operation (homes, offices, transport networks) and living (televisions, air conditioners, cooking, computers, etc). Today, the residential household energy consumption is almost a third of all end-use energy. Households are also indirectly responsible for a large amount of energy use, required in production and freight of the goods and services they consume. Therefore, the households in some countries are ultimately responsible for over half of total energy use either directly or indirectly through the consumption of products and services. In countries with a temperate climate, more than half of this energy is typically used for heating (IEA, 2004). Although energy use for space cooling is relatively less, it is on the rapid rise both in high-income countries as well as in emerging economies including India, China and some countries in the Middle East, South East Asia and South America. Energy demand for heating and cooling is greater than ever. As most available energy is based on fossil fuel, the increased energy demands contribute significantly to more greenhouse gas emissions (Alam & Theos, 2008). The residential household energy uses in the U.S. and Australia are one of the highest in the developed world. In 2001, the residential sector in the U.S. used approximately 21 trillion joules of site energy per year; this amounts to approximately 20% of all energy use in the country and 27% when confined to the non-transportation sector. Moreover, American households consumed almost 35% of all national electricity production (3,660 billion kWh) and strongly depend on natural gas for heating (Diamond & Moezzi, 2002). Furthermore, supplying energy to the residential sector in the U.S. generated over 18% of its greenhouse gas emissions. Despite technological improvements in refrigerator, furnace efficiency and energy codes improving insulation, many American lifestyle changes have put higher demands on heating and cooling systems. A similar trend in energy consumption was also found in the Australian household energy use. The energy used in Australian households is one of the largest sources of CO_2 from the combustion of fossil fuels (hydrocarbon) according a report by the Australian Bureau of Statistics in 2001. The average Australian household is responsible for the generation of approximately 8 tonnes of CO_2 each year which is almost 3077 kg per person for a 2.6 person household equivalent to the weight of five average sized family cars (AGO, 2004). The greenhouse gas emission related to the residential household energy use in Australia is significantly higher compared to the household energy use in the U.S. due to the fact that most energy (electricity) is generated by using coal. Therefore, the primary objective of this paper was to depict a comparative picture of household energy use both in Australia and the U.S.

2 CONSUMPTION PATTERN- HISTORIC TRENDS

In early 1800, both Australia and the U.S. were predominantly agrarian countries and their energy needs were met using primarily firewood. However, with the rapid growth of industrialisation, urbanisation and rail and road infrastructure, the energy needs have initially met using coal till mid 1900 and now primarily by the petroleum and natural gas. In Australia, the use of coal is still dominant. The residential dwellings and households are generally built in a

large variety of configurations. The following types of residential dwellings are being built in Australia and the U.S.

a) Detached dwelling (single and double storey)
b) Semi-detached dwelling (duplex/town houses)
c) Attached dwelling (multi unit houses, flats and apartments)
d) Movable dwelling (houseboat, caravan)

Approximately 80 percent of the residential household used energy is consumed in single family homes (detached dwellings), while 15 percent is consumed in multi-family dwellings such as apartments, and 5 percent is consumed in mobile homes according to the U.S. Energy Information Administration (BEDB, 2008).

The energy consumption pattern largely depends on the types of dwelling, occupant numbers, household incomes and climatic zones. Most household energy consumption is due to largely heating and cooling, hot water system, lighting and appliances.

2.1 Households

The U.S. is the 3rd largest country in terms of population and it has approximately 117 million residential dwellings compared to Australia with a population of just over 21 million and 8.5 million dwelling houses. The growth of population and residential dwellings has been increased over the decade in both countries (see Figure 1 and Figure 2). More than 1.8 million residential buildings are built annually in the U.S. according to the 2006 Annual Housing Starts report (U.S. Census Bureau, 2006). At present, over 140,000 new residential houses are built in Australia each year and the demand is significantly more (Alam & Theos, 2008; EUARS, 2008). Whilst population growth and residential dwelling in US have increased approximately 22% and 24% respectively, the Australian population has increased 23.5% along the residential dwelling increase of approximately 42% in 2008 compared to 1990. The average floor area per household in both countries has also increased significantly. In Australia, it increased from 114 m² in 1990 to 142 m² in 2008, i.e., an increase of 25% over the period of 1990-2008 according to a report on Energy Use in the Australian Residential Sector 1986-2020 by the Department of the Environment, Water, Heritage and the Arts, Australian Government (EUARS, 2008). The larger floor area not only increases the construction cost (approximately A$1,200 per square meter) but also consumes more energy for heating, cooling and lighting for extra spaces resulting in the significant rise of greenhouse gas emission (Alam & Theos, 2008).

Despite technological improvements in heating and cooling systems, appliances efficiency, and energy efficient construction and building, lifestyle changes have put higher demands on heating and cooling systems. As the average size of homes built in the U.S. has increased significantly from 139 m² in 1970 to 214 m² in 2005, the two-person household in a large home has become more common, as has central air conditioning: 23% of households had central air conditioning in 1978 and that figure rose to 55% by 2001 (diamond & Moezzi, 2002). Additionally, miscellaneous electric end-uses in households since 2000 has been rapidly expanding, largely offsetting efficiency gains in the conventional end-uses of heating, cooling and water heating. Overall energy use from fridges and freezers is declining due to the improved energy consumption of new fridges. The energy usage for hot water system can remain unchanged or decline due to the move away from electric heating (primarily storage systems) towards natural gas or solar with gas or electric boosting. However, the use of solar hot water systems has changed little in energy consumption share over the past decade as they were not widely used due to lack of knowledge and efficiency. Today, most solar thermal hot water systems available in the U.S. and Australian markets are efficient, well designed and cost effective. Thanks to various policies and initiatives taken by the governments and regulatory authorities, the use of solar thermal hot water systems is expected to increase rapidly over the next decade both in Australia and the U.S. At present, most newly built residential houses in Australia are generally equipped with the solar thermal hot water systems.

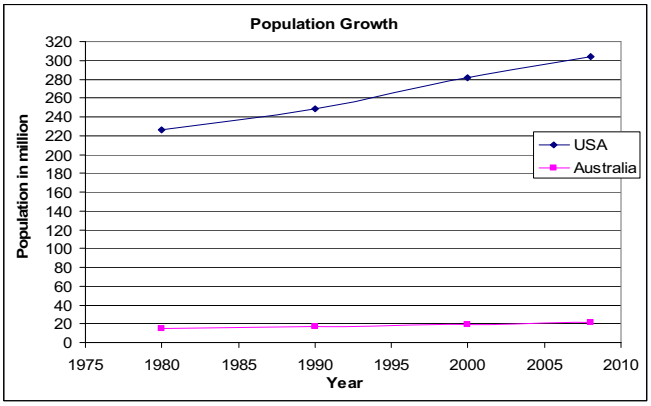

Figure 1 Population growth in USA and Australia.

In contrast, energy use from personal computers and associated equipment, and entertainment units has been growing rapidly and by 2020, it is projected to almost match space heating as the largest single energy end use in the average Australian household, especially in the Northern Australia. The population growth in Northern Queensland in Australia has increased significantly over the past decade. Most residential households needs more energy for cooling due to humid and tropical or sub tropical climate compared to the households located in the southern part of the country. On the other hand, the households in Southern Australia need more energy for heating as they experience relatively cooler climatic zone. This energy use disparity is more evident in the U.S. due to its varied and extreme climatic zones. The hot southern states need more energy for cooling than those located in the north. Conversely, the northern states need more energy for heating than those are in the south. Currently, space cooling (air-conditioning) is predicted to show the most rapid growth in energy use over the study period with an average growth of 16.1% per annum. Therefore, it is likely that this estimated growth in energy use

in the residential sector will result in a significant growth in greenhouse gas emissions.

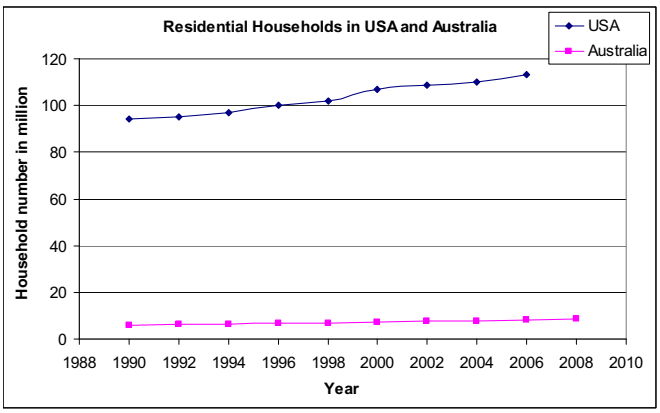

Figure 2 Residential households in USA and Australia since 1990.

2.2 Electricity and Gas Consumption

As mentioned earlier, the lion share of residential household energy is required for hot water system, space heating and cooling. Buildings account for nearly 40% of total U.S. energy consumption. Households use about one-fifth of the total energy consumed in the U.S. each year; the residential sector is contributing 21% of the U.S.'s carbon dioxide emissions, according to the U.S. Department of Energy's Energy Information Administration (BEDB, 2005; REC, 2001).

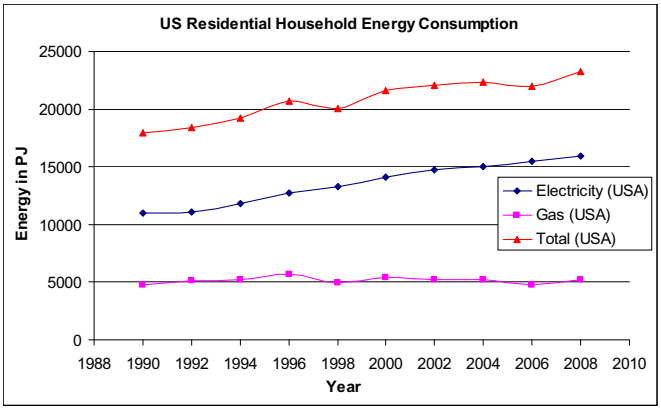

Figure 3 Household Energy Consumption in the U.S., adapted from (Diamond & Moezzi, 2002; IEA, 2004).

The average household spends some U$1,500 each year on energy bills. Electronic devices in standby mode account for 10% of home energy use which is up from 2% in 1980, according to the U.S. Environmental Protection Agency (EPA, 2008). The electronic appliances include most devices with a remote control, such as televisions, that are in 'power off' mode but are still plugged in. Average daily U.S. carbon dioxide gas emissions per person are around 55.5 kg (world average is approximately 11 kg) according to the U.S. Green Building Council (GBC, 2008; AEO, 2008). The more updated U.S. household energy consumption from 1990 to 2008 is shown in Figure 3. The Figure indicates that the electricity consumption has steadily increased over the time (almost 45% increases in 2008 compared to 1990). Meanwhile, the gas consumption is almost steady over the same period (only 10% increase). The modest increase in gas use reflects the drop in energy for space heating and the shift to electricity (Battles & Burns, 2000). The increase in electricity is due to greater air conditioning use (both in volume of space conditioned as well as hours of usage) as well as other electrical and electronic appliances usage including computers and large screen plasma and LCD TVs, switching from gas to electric (heat pumps, water heaters), and other factors, such as demographic shifts to the South (Schipper & Ketoff, 1989).

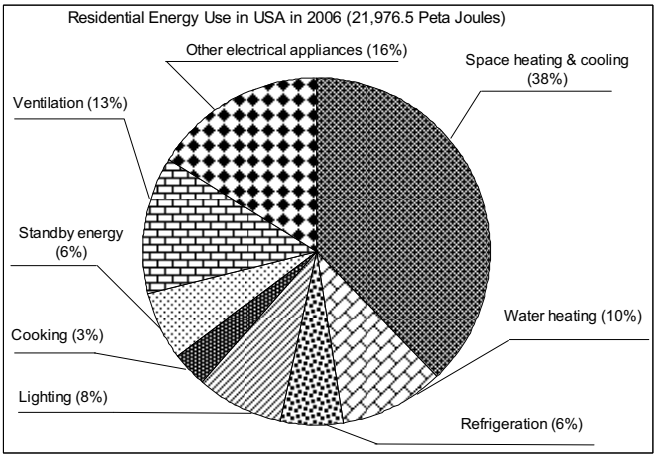

Figure 4 Residential household energy use in U.S. in 2006 (21,976.5 Peta Joules), adapted from (Diamond & Moezzi, 2002; IEA, 2004).

Governmental policies for rural electrification, e.g., the Tennessee Valley Authority, also subsidized electricity use and growth in the Southeast, Northwest and elsewhere. Although modern residential houses and household appliances are more energy efficient, the increase in house size over this time, as well as the increase in appliance saturation and usage are believed to be the additional drivers behind the increase of energy consumption (Alam & Theos, 2008). As mentioned earlier, the average new house floor area in U.S. has increased from 91.3 m² in 1950 to 211 m² in 2000, more than doubling.

As household size has decreased, the floor area per capita has increased by a factor of 2.9, from 27 m² per capita in 1950 to 79 m² per capita in 2000. The ratio is believed to be more in 2008. A pictorial view of averaged household energy use in 2006 is shown in Figure 4. It illustrates that the heating and cooling are the major consumer of household energy (approximately 38%). Due to varied climatic zones and building styles, a significant portion of energy is required for ventilation.

A comparable trend of residential household energy use is also noted in Australia. Figure 5 illustrates the average Australian residential household energy use of electricity and gas over the period of 1990 to 2008. The Figure indicates that both electricity and gas consumption has increased significantly. The consumption of electricity increased to 48% in 2008 compared to 1990. On the other hand, there is nearly 56% increase in gas use in 2008 compared to 1990. Although the Australian population has increased by 23.5% in 2008 from 1990, the residential dwelling has increased to approximately 42% in 2008 from 1990. The average floor area per household in Australia has increased from 114 m² in 1990 to 142 m² in 2008 (an increase of over 25% over the period of 1990-2008) [3, 8]. The electricity consumption increase is primarily due to continuous growth in air conditioning use (both in volume of space conditioned as well as hours of usage) as well as other appliance usage including computers and large screen plasma and LCD TVs and other factors, such as demographic shifts to the Southern and Eastern Australia.

The gas consumption increase is believed to be due to larger space heating, hot water system, and generation of electricity (power). As mentioned earlier the modern residential houses and appliances are 25-40% more energy efficient compared to two decades ago, the increase in house floor size and ceiling height over this time (1990-2008), as well as the increase in appliance saturation and usage are believed to be the additional factors for the increase of energy consumption (Alam & Theos, 2008). Akin to the U.S., the hot water systems, heating and cooling require most energy, consumed by the residential buildings in Australia (see Figure 6).

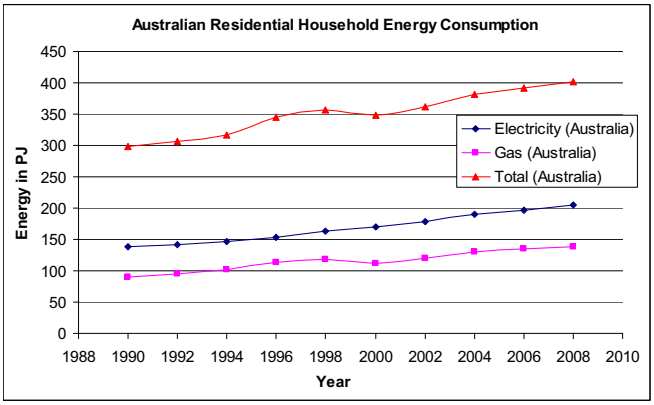

Figure 5 Household energy consumption in Australia, adapted from (ABS, 2008).

The space heating and cooling for the Australian residential households is the highest consumer of energy (39%) and the second highest consumer is the hot water system (30%). Energy required for cooking and lighting is minimal (4% and 5% respectively). The wood energy consumption has been decreased significantly over the years in Australia as well as in the U.S. and the use will continue to fall in the future (data not shown here). The traditional wood heating is gradually being replaced with the electric and/or gas heating. The wood energy consumption has been decreased significantly over the years in Australia as well as in the U.S. and the use will continue to fall in the future (data not shown here). The traditional wood heating is gradually being replaced with the electric and or gas heating.

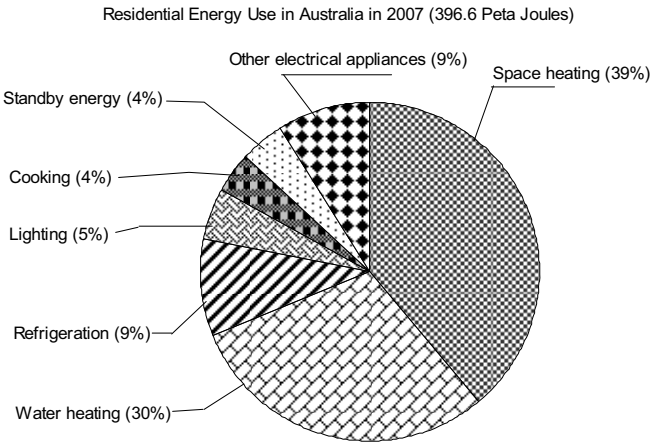

Figure 6 Residential household energy use in Australia in 2007 (396.6 Peta Joules), adapted from (ABS, 2008).

3 INTERNATIONAL COMPARISON OF ENERGY USE

As it is generally difficult to measure the energy performance of countries that are significantly different due to varied climatic conditions, industrial structures, geographical features and economic development. The changes in the aggregate energy intensity ratio (energy consumed per unit of output) are an inadequate basis for measuring and comparing energy efficiency among countries. However, Table 1 and 2 present some international comparisons of energy performance The data presented in Table 1 and 2 is adapted from (AGO, 2004; ABS, 2008; IEA, 2004) and OECD/IEA 2002 and is valid from 1990 to 2000.

Table 1 shows that the U.S. is the world top energy producer followed by Canada, UK and Australia. However, Australia is the only country outside OECD European countries which has increased its energy production almost 47% in 2000 from that in 1990 primarily due to its population increase, relatively larger dwelling size and industrialisation. While the United States energy production has increased approximately 2% during the same period (1990-2000), Germany is the only country that produced less energy in 2000 than in 1990 (almost 28%) thanks to the energy import from Russia (gas almost 40%). The means of electricity generation of selected OECD[1] countries including USA and Australia is shown in Table 2. It is clearly evident that the Australian electricity (power) generation almost entirely depends on coal (around 72%). The U.S. and Germany's power generation also depends heavily on coal (approximately 53%) and is second to Australia.

Therefore, it is no wonder why these countries generate more per capita greenhouse gas emission than other developed

countries. On the other hand, Norway is the only country which generates its power entirely from hydro (99.5%) followed by New Zealand (63%) and Canada (59%). France heavily relies on nuclear power for its electricity generation (almost 76%). The use of electricity has significantly increased in most developed countries including Australia and U.S. due to increased electricity use for air conditioning, heating, cooking, lighting, computing and other household appliances. Significant growth in residential energy use over the past two decades can be attributed to rapid increase of household appliance ownership in Australia. However, the use of electricity for household appliances in the U.S., Canada and OECD Northern European countries is lower compared to Australia due to the fact that the consumption was almost saturated in the last two decades (data not shown here).

Table 1: Energy Indicators for Selected OECD Countries in 2000 (BEDB, 2005; EUARS, 2008)

	Energy productio	Change from 1990	TPES(a)	Change from 1990	TPES(a)/ GDP(b)	Change from 1990	TPES(a)/ Population	Change 1990 from to 2000
	Mtoe(c)	%	Mtoe(c)	%	toe/$US	%	toe/capita	%
Australia	**232.55**	**47.5**	**110.17**	**25.1**	**232.8**	**-11.4**	**5.8**	**13.3**
Canada	374.86	37	250.97	19.1	306.8	-8.7	8.2	8.8
Denmark	27.87	170.6	19.46	6.6	141.8	-14.6	3.6	2.6
Finland	15.13	29.1	33.15	16.5	268.8	-7.1	6.4	10.9
France	131.38	18.7	257.13	16.3	189.6	-4.5	4.3	10.5
Germany	134.32	-27.6	339.64	-4.3	177.8	-19.3	4.1	-8.3
Italy	26.86	9.1	171.57	10.9	135.5	-3.3	3	12.4
Netherlands	57.24	-4.6	75.8	14.1	192.6	-14.3	4.8	8.1
New Zealand	15.38	25.4	18.63	33	261.1	1	4.9	17.8
Norway	224.99	87.4	25.62	19.1	216.9	-14.3	5.7	12.9
UK	272.69	31.1	232.64	9.8	184.1	-12.6	3.9	5.7
USA	**1,675.77**	**1.6**	**2,299.67**	**19.8**	**255.9**	**-13.4**	**8.3**	**7.8**
OECD(d)	3,826.49	12.2	5,316.93	30.3	215.9	-8.9	4.7	8.8

(a) Total primary energy supply (TPES) is made up of production plus imports less exports less international marine bunkers, net of stock changes.
(b) Gross domestic product (GDP) in purchasing price parity terms, expressed in 1995 $US.
(c) Million tonnes of oil equivalent.
(d) All other OECD countries.

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Table 2: Fuel Shares in Electricity Generation, Selected OECD countries in 2000 [6, 8]

	Coal	Petroleum	Natural gas	Fossil fuels	Nuclear	Hydro-electricity	Geothermal & solar	Combust. renew. and waste
	%	%	%	%	%	%	%	%
Australia	**77.2**	**1.3**	**12.6**	**91.1**	**-**	**8.1**	**-**	**0.8**
Canada	19.5	2.5	5.5	27.5	12	59.2	-	1.2
Denmark	46	12.2	24.3	82.5	-	0.1	12.3	5.1
France	5.8	1.4	2.1	9.3	77.5	12.5	0.1	0.6
Germany	52.7	0.8	9.3	62.8	29.9	3.8	1.7	1.8
Italy	11.3	31.8	37.5	80.7	-	16.4	2.2	0.7
Netherlands	28.4	3.5	57.7	89.6	4.4	0.2	1.2	4.7
New Zealand	2.6	-	23.8	26.4	-	63.1	8.9	1.5
Norway	0.1	-	0.1	0.3	-	99.5	-	0.2
UK	33.4	1.5	39.4	74.3	22.9	1.4	0.3	1.2
USA	**52.7**	**3.1**	**15.7**	**71.6**	**20**	**6.2**	**0.5**	**1.7**
OECD(a)	38.8	6.2	15.8	60.8	23.3	13.7	0.7	1.5

(a) All other OECD countries.

[1] The Organisation for Economic Co-operation and Development (OECD) consists of mainly 30 developed countries and originally formed in 1961: Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, USA, Japan, Finland, Australia, New Zealand, Mexico, Czech Republic, South Korea, Hungary, Poland & Slovakia.

4 CONCLUDING REMARKS

The analysis of energy consumption by the U.S. and Australian residential households indicates a comparable energy consumption pattern in both countries. Although the U.S. remains the larger consumer of energy, the per capita energy consumption in Australia is significantly higher. In the U.S., the electricity consumption has increased over the last 10 years compared to Australia where both electricity and gas consumptions have increased over the same period.

Australia and the U.S. significantly rely on coal for the generation of their electricity (power). As a result, the coal fired power stations generate considerable greenhouse gas emissions. In order to reduce the environmental pollution, both Australia and the U.S. need to seek alternative means for their power generation.

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